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TABLE OF CONTENTS

Vol. 19 October, 1936 No. 10

THE JOURNAL

Testing Refractories against the Corrosive Action of Electric Furnace Phosphate Slags 259
By G. R. Pole and D. G. Moore

Quartz as a Devitrification Product of Vitreous Silica 271
By L. J. Trostel

Comparison of the Thermal Expansion of Used Silica Brick from an Insulated and an Uninsulated Open-Hearth Furnace Roof 276
By R. H. H. Pierce, Jr., and J. B. Austin

Spit-Out 287
By C. J. Koenig

Use of Syenite in Semivitreous Ware, I: (*a*) Physical Properties of Bisques; (*b*) A Glaze Containing Syenite 295
By C. J. Koenig

Measurement and Significance of Enamel Thickness 298
By H. H. Holscher

The Effect of Hydrochloric Acid and Ammonia on Properties of Some Reworked Bodies 304
By Robert Twells

CERAMIC ABSTRACTS

15—10

Abrasives 291
Art and Archeology 292
Cements 293
Enamel 294
Glass 295
Structural Clay Products 300
Refractories 301
Terra Cotta 305
Whiteware 306
Equipment and Apparatus 307
Kilns, Furnaces, Fuels, and Combustion 309
Geology 311
Chemistry and Physics 313
General 317

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TESTING REFRACTORIES AGAINST THE CORROSIVE ACTION OF ELECTRIC FURNACE PHOSPHATE SLAGS*

By Gordon R. Pole and D. G. Moore

Abstract

A new method was developed as a means of testing refractories against molten phosphate furnace slag at 1450°C. The slag was essentially a monocalcium silicate. Brick with $13^1/_2$- by $4^1/_2$- by $2^1/_2$-inch dimensions were used as test specimens. An oil-fired pot-type furnace, 24 inches in diameter and 12 inches deep, was used for the test. Four refractories were tested at one time by this method. The test brick were suspended from a silicon carbide crown and dipped $2^1/_2$ inches into the molten slag bath. The degree of corrosion was measured by determining the volume and weight losses of the refractory. Petrographic studies were made on a number of the brick after testing. Quantitative data on twenty-two brands of refractories tested by this means are given.

I. Introduction

The purpose of this investigation was to determine what types of refractories were best suited to resist the erosion and chemical action of molten phosphate furnace slags obtained from the electric furnace reduction of phosphate rock.

(1) Review of Literature

A fairly comprehensive review of the literature up to 1928 covering the testing of refractories against slag attack is given by Ferguson,[1] who concluded that no single laboratory slag test has been developed that meets universal approval.

Simpson[2] continued this review and gives a résumé of the various tests used by different investigators up to 1931. He classified these tests under eight headings and concluded that a slag test that would show chemical attack as well as penetration would obviously have the greatest value. He also pointed out that more intensive use of thin sections of slag and refractory with the petrographic microscope offers considerable promise in solving slagging problems.

Partridge[3] gave a complete review of the various methods that have been used in testing refractories against slag and glass attack. This article has a bibliography of 178 references. Partridge concluded that the corrosion test in small-scale tank furnaces probably is the most practical test for glass refractories.

It can be concluded from a study of the results of previous investigations that the ideal slagging test is one that simulates actual service conditions and in which fairly accurate measurements can be made of the effect of the various factors causing the disintegration of the refractory, as well as accurate measurements of the quantitative results of a given test.

II. Experimental

(1) Materials

Test Brick: The test brick used in these corrosion studies were standard $13^1/_2$- by $4^1/_2$- by $2^1/_2$-inch straights obtained from various producers. Twenty-two brands of brick made by twelve different manufacturers were tested. The kind of refractories tested and their chemical analyses are given in Table I.

Slag: The slag was obtained from the electric furnace reduction of phosphate rock. The fines were removed from the regular plant slag of approximately 2-inch size by screening on a sieve with openings $^1/_2$ inch square with only the oversize being used. The slag started to soften at cone 5 and became quite fluid at 1425°C. The composition of this slag is not greatly different from certain blast-furnace slags used in the manufacture of Portland cement. The blast-furnace slags tend to have higher alumina and magnesia contents. The average composition of the phosphate furnace slag taken over a period of one month was as follows:

Average Analysis of Phosphate Furnace Slag

	(%)
SiO_2	39.3
CaO	49.6
P_2O_5	1.8
F	3.0 (approx.)
R_2O_3	6.3 (by difference)

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, March 31, 1936 (Refractories Division).

[1] R. F. Ferguson, "Review of Literature on Laboratory Slag Tests for Refractories," *Jour. Amer. Ceram. Soc.*, 11 [2] 90–98 (1928).

[2] H. E. Simpson, "Classified Review of Refractory Slag Tests," *ibid.*, 15 [10] 536–44 (1932).

[3] J. H. Partridge, "Review of Problem of Tank Blocks for Glassmelting Furnaces," *Jour. Soc. Glass Tech.*, 17 [66] 169–238 (1933); *Ceram. Abs.*, 13 [2] 36 (1934).

TABLE I

CHEMICAL ANALYSES OF REFRACTORIES USED IN SLAG TEST

Laboratory No.	Kind of refractory	SiO_2 (%)	TiO_2(%)	Fe_2O_3(%)	Al_2O_3(%)	CaO(%)	MgO(%)	Total(%)
C-1	Silicon carbide*	7.1†		0.5	3.4	1.7		100.0
E-2	Magnesite	4.9		2.0	0.4	4.8	88.1	100.2
M-1	Mullite (fused)	17.5	3.0	1.0	77.6	1.2	0.3	100.6
S-2	Silica	93.2		1.8	0.2	3.2	1.0	99.4
H-2	Magnesite	2.7		3.6	0.4	6.8	87.3	100.8
R-2	Mullite	42.0	1.3	0.9	53.3	1.0	1.9	100.4
T-1	"	37.2	1.6	0.9	57.5	1.0	1.6	99.8
H-6	Fire brick	50.9	2.6	1.1	43.8	1.4	1.4	101.2
G-6	" "	53.4	3.3	0.2	42.8	0.1	0.1	99.9
K-3	" "	50.3	1.5	1.4	44.7	1.0	1.8	100.7
F-4	Glass refractory	67.1	2.7	1.8	27.1	0.9	1.0	100.6
G-7	Diaspore brick	33.1	4.5	Trace	61.8	0.4	0.2	100.0
P-3	Glass refractory	60.9	1.9	0.5	36.8	0.6	0.5	101.2
F-1	" "	59.9	3.0	0.4	37.1	0.7	0.7	101.8
L-1	" "	69.8	2.1	1.4	26.6	0.7	0.7	101.3
W-3	Fire brick	57.6	2.6	1.1	38.5	1.0	1.0	101.8
D-1	" "	66.8	2.3	2.0	26.6	1.0	1.8	100.5
H-5	" "	59.8	2.0	2.5	32.5	0.9	1.6	99.3
A-1	Chrome‡	6.4	0.8		21.9	2.0	27.8	101.0
H-7	Forsterite	35.0		3.1	0.9	21.0	39.7	99.7
B-1	Glass refractory	64.7	2.5	0.4	31.5	0.6	0.2	99.9
L-5	" "	67.7	2.0	2.6	26.1	1.0	1.1	100.5

* Contains 87.4% SiC.
† By difference.
‡ Contains 29.2% Cr_2O_3 and 12.9% FeO.

TABLE II

PHYSICAL PROPERTIES OF REFRACTORIES USED IN SLAG TEST

Laboratory No.	Kind of refractory	Apparent specific gravity	Bulk specific gravity	Porosity (%)	P.C.E. (cones)	Corrosion test (weight loss %)	Corrosion test volume (loss %)
C-1	Silicon carbide	3.07	2.42	21.3	No test	5.9†	0.1
E-2	Magnesite	3.48	2.76	20.5	35*	21.5†	9.8
M-1	Mullite (fused)	3.33	3.26	2.1	36*	30.4	31.7
S-2	Silica	2.32	1.80	22.7	31–32	2.4	35.0
H-2	Magnesite	3.50	2.54	27.2	35*	13.7†	End dropped off
R-2	Mullite	2.95	2.14	27.6	35–36	46.2	49.0
T-1	"	2.99	2.13	28.7	36	48.3	52.5
H-6	Fire brick	2.72	2.39	11.8	34	56.1	57.5
G-6	" "	2.70	2.39	11.4	34	67.3	60.7
K-3	" "	2.63	2.11	19.6	34	58.4	68.2
F-4	Glass refractory	2.58	2.25	12.5	30	63.7	64.5
G-7	Diaspore brick	2.98	2.15	28.1	35–36	64.2	67.4
P-3	Glass refractory	2.62	2.18	16.6	32–33	79.7	82.1
F-1	" "	2.64	2.21	16.5	32–33	72.3	92.5
L-1	" "	2.64	1.89	28.5	28	74.8	100.7
W-3	Fire brick	2.67	2.04	23.5	32–33	87.5	92.3
D-1	" "	2.61	1.85	29.0	30–31	84.0	90.2
H-5	" "	2.58	1.97	23.5	32–33	80.4	83.6
A-1	Chrome	3.91	2.63	32.5	35*	80.0	104.0
H-7	Forsterite	3.37	2.37	29.7	35	63.7	100.0
B-1	Glass refractory	2.64	1.91	27.6	29	Spalled	Spalled
L-5	" "	2.63	1.94	26.2	29	"	"

* P.C.E. higher than cone indicated.
† Gain in weight.

III. Method of Testing

(1) Preparation of Test Brick

Each refractory prior to testing was examined for noticeable defects, and its dimensions were measured to the closest one-sixteenth inch. After the brick had been weighed to the nearest gram, it was given a thin coating of paraffin by dipping in a shallow pan of the melted material. Care was taken to waterproof thoroughly the outside surface of the brick. The volume of the test brick was then determined by the displacement method, using an overflow volumeter in which water was the liquid medium. By this means the volume of a brick of approximately 2500 cubic centimeters could be determined with an error of less than 1%.

Steel clamps were then fastened to one end of

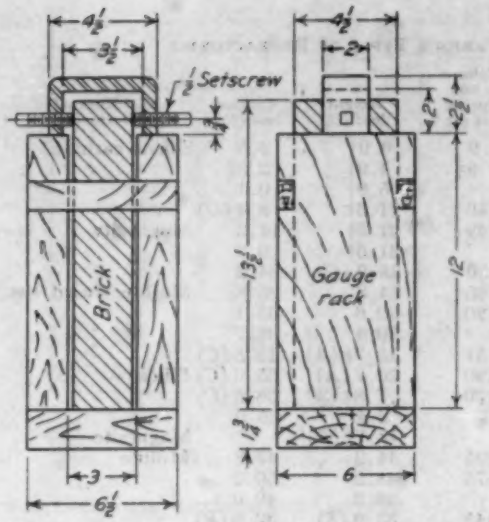

FIG. 1.—Gage rack and steel clamp for slag test brick.

each brick by means of setscrews. The function of the clamp was to hold the brick at a constant depth of immersion when suspended from the furnace top. A constant distance of twelve inches of suspension was maintained by placing the test brick in a gage rack (see Fig. 1). The two set-

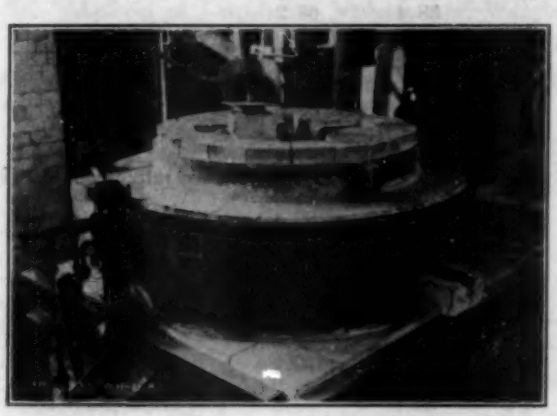

FIG. 2.—Refractory slag testing furnace.

screws were then tightened sufficiently to mark spots for drilling the shallow holes.

(2) Testing Furnace

Figure 2 is a photograph of the furnace showing the essential parts, and Fig. 3 shows the construction details of the furnace and the arrangement of the test brick.

The furnace was heated by means of two No. 530 Hauck Venturi high-pressure oil burners. With 60 pounds air pressure and 30 pounds oil pressure, using a 30° Bé fuel oil, the maximum temperature reached was only 1300°C. To reach higher temperatures, a $^1/_4$-inch auxiliary air pipe was placed at the base of each burner port. By

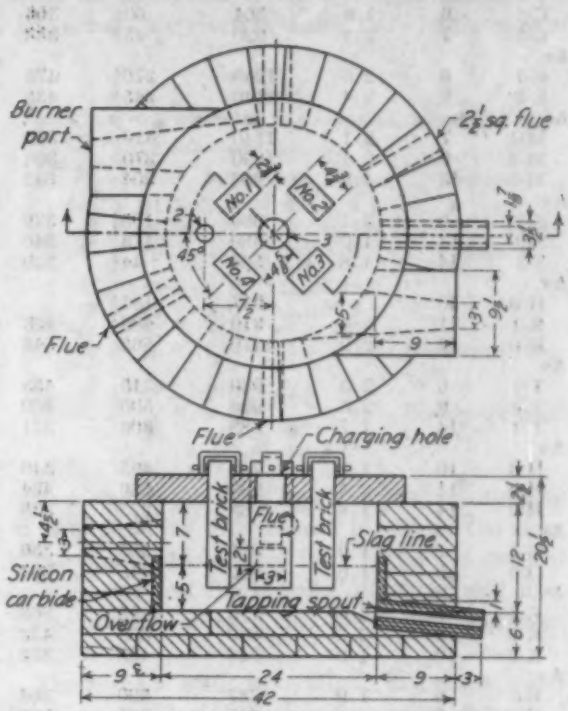

FIG. 3.—Refractory slag testing furnace.

means of these secondary air jets at 80 pounds air pressure, 1450°C could be reached with little trouble. The air jets were directed down toward the inside walls and served to keep the molten slag moving during the test. During a regular run the melted slag made approximately 5 to 6 revolutions per minute in the furnace.

The test brick were suspended through four

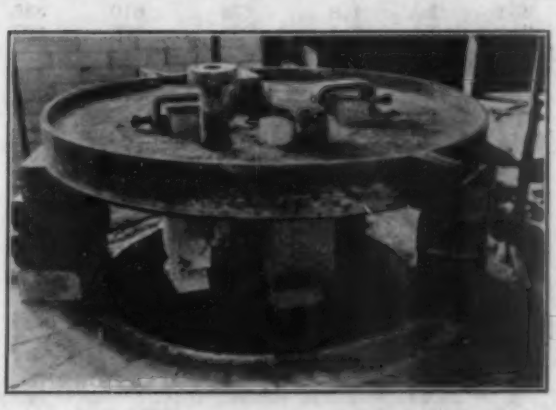

FIG. 4.—Silicon-carbide furnace top.

TABLE III

SUMMARY OF RESULTS OF SLAG TEST ON VARIOUS TYPES OF REFRACTORIES

Laboratory No.	Test No.	Depth of immersion (in.)	Weight of immersed end (grams)	Weight loss during test (grams)	Volume of immersed end (cc.)	Volume loss during test (cc.)	Weight loss (%)	Volume loss (%)	Kind of refractory
C-1	6	1.9	864	60†	366	9	6.9†	2.5	Silicon carbide
C-2	7	2.1	920	45†	388	9†	4.9†	2.3†	
Av.							5.9†	0.1	
E-1	8	2.6	1248	270†	475	40	21.6†	8.4 (*D*)	
E-2	9	2.4	1140	245†	435	49	21.5†	11.2	Magnesite
Av.							21.5†	9.8	
M-1	7	2.1	1140	410	380	130	35.9 (*C*)	34.2	
M-2	9	2.1	1090	270	368	95	24.8	25.8	Mullite (fused cast)
M-3	13	1.9	995	304	342	120	30.6	35.1	
Av.							30.4	31.7	
S-1	9	2.1	669	105†	379	51	15.7† (*A*)	13.5 (*C*)	
S-2	13	1.9	580	178	346	190	30.7 (*A*)	55.0 (*C*)	Silica
S-3	14	1.8	564	44†	329	120	7.8† (*A*)	36.5 (*C*)	
Av.							2.4	35.0	
H-2	10		947	130†			13.7† (*D*)		Magnesite
R-1	11	2.4	910	402	428	205	44.2	47.8	Mullite
R-2	12	2.9	1170	565	548	275	48.2	50.2	
Av.							46.2	49.0	
T-1	6	2.5	930	315	453	145	33.9 (*R*)	32.0 (*R*)	
T-2	9	2.5	966	500	460	260	51.7	56.5	Mullite
T-3	14	1.7	683	306	321	156	44.8	48.6	
Av.							48.3	52.5	
H-3	10	1.9	798	465	340	209	58.2	61.5	
H-6	11	2.4	993	536	424	232	54.0	54.7	Fire brick (Missouri)
H-9	14	1.8	768	273	335	189	35.6 (*R*)	56.4	
Av.							56.1	57.5	
G-1	1	1.9	815	565	350	217	69.3	62.0	Fire brick(Missouri)
G-6	5	1.6	882	445	294	175	65.3	59.5	
Av.							67.3	60.7	
K-1	7	2.0	770	445	368	241	57.8	65.5	Fire brick (kaolin)
K-2	8	2.3	880	535	432	297	60.8	68.8	
K-3	10	1.9	716	405	352	247	56.5	70.2	
Av.							58.4	68.2	
F-3	6	1.9	787	520	364	242	66.0	66.5	Glass refractory
F-4	5	1.6	643	395	288	180	61.4	62.5	
Av.							63.7	64.5	
G-3	2	1.7	642	425	301	195	66.3	64.8	Fire brick (diaspore)
G-7	6	2.2	647	590	396	273	69.6	68.8	
G-8	14	1.9	710	403	342	235	56.8	68.7	
Av.							64.2	67.4	
P-2	2	1.7	697	565	322	257	81.0	80.0	Glass refractory
P-3	13	1.7	698	548	322	272	78.5	84.3	
Av.							79.7	82.1	
F-1	3	1.6	646	475	295	295	73.5	100.0 (*C*)	Glass refractory
F-2	3	1.6	646	460	293	250	71.2	85.0	
Av.							72.3	92.5	
L-1	3	1.6	544	420	288	271	77.2 (*C*)	94.1	
L-2	3	1.6	540	410	291	303	76.0 (*C*)	104.0 (*S*)	Glass refractory
L-4	5	1.6	540	385	287	300	71.3 (*C*)	104.0 (*S*)	
Av.							74.8	100.7	
W-1	1	1.8	674	610	336	316	90.5	94.0	
W-3	7	2.1	798	675	397	359	84.5	90.5	Fire brick (Missouri)
Av.							87.5	92.3	
D-1	11	2.2	765	623	412	361	81.5	87.5	Fire brick(Birmingham)
D-2	12	2.6	920	914	498	495	99.3 (*R*)	99.4 (*R*)	
D-3	13	1.7	608	526	331	308	86.5	93.0	
Av.							84.0	90.2	
H-4	10	1.9	688	555	358	295	80.7	82.5	
H-5	11	2.4	840	672	438	372	80.0	84.8	Fire brick (Birmingham)
Av.							80.4	83.6	
A-1	8	2.8	1380	1105	537	557	80.0 (*A*)	104.0	Chrome
H-7	12	2.9	1180	741	510	510	62.8 (*A*)	100 (*D*)	
H-8	12	2.9	1260	815	525	525	64.6 (*A*)	100 (*D*)	Forsterite
Av.							63.7	100	
B-1	4						Spalled	Spalled	Glass refractory
B-2	5						Spalled	Spalled	Glass refractory
L-5	8								

† = gain in weight or volume.
(*A*) = absorbed slag.
(*C*) = cracked during test.
(*D*) = end dropped off after test.
(*R*) = rejected.
(*S*) = shrinkage.

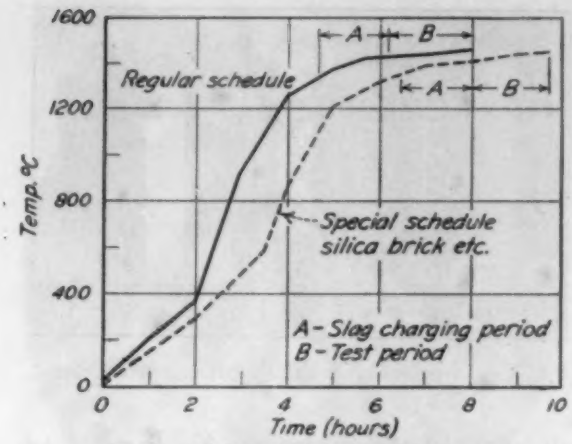

FIG. 5.—Firing schedules for slag test.

holes in the silicon-carbide top (see Fig. 4). The heating-up schedule varied as shown in Fig. 5.

After the test period, the slag was tapped from the furnace. The temperature was maintained at 1450°C during the tapping period to drain the test brick free of molten slag. This tapping period usually required from 10 to 15 minutes after which the furnace was shut down and allowed to cool for about 12 to 16 hours.

IV. Method of Calculating Volume and Weight

The following data illustrate the method used in calculating the volume and weight losses in terms of the depth of immersion.

LOSSES OF REFRACTORY SLAG TEST

Length of refractory before test (in.)	13.5
Depth of immersion (in.)	2.5
Weight of refractory before test (grams)	5000
Volume of refractory before test (cc.)	2400
Weight of immersed end before test (grams)	(2.5/13.5) × 5000 = 926
Volume of immersed end before test (cc.)	(2.5/13.5) × 2400 = 444
Loss of weight of refractory after test (grams)	300
Loss of volume of refractory after test (cc.)	150
Loss in weight (%)	300/926 = 32.4
Loss in volume (%)	150/444 = 33.8

V. Experimental Results

The results of the slag test made on twenty-two brands of refractories are given in Table III. The analyses of the slag after test are given in Table IV. Photographs of twenty brands of test brick made after the slag corrosion test are shown in Figs. 6 to 10, inclusive. Photomicrographs of thin sections of four test brick and the phosphate furnace slag are shown in Figs. 11 to 17.

VI. Discussion

(1) Phosphate Furnace Slag

Analyses of the slag were made after every test with the exception of tests 4, 8, 9, 13, and 14. The results are given in Table IV. In the case of tests 8 and 9, the same batch of slag was used as in test 7, and for tests 13 and 14, slag of the same batch was used as for test 12. Test 4 was stopped because one test brick broke off at the slag line. These analyses showed that the variation in composition was quite small.

TALBE IV

ANALYSIS OF PHOSPHATE SLAG AFTER CORROSION TEST

Test No.	Composition (%) SiO_2	CaO	P_2O_5	Fe_2O_3	Al_2O_3	Remarks
1	43.8	41.8	3.9	0.6	8.9	
2	43.5	44.0	1.7	0.1	13.4	
3	41.7	43.1	1.7	Trace	10.9	Percentage F = 0.5
5	43.7	41.9	1.8	0.1	10.3	
6	42.9	42.9	2.0	1.8	9.4	
7	43.7	42.7	1.9	0.4	10.7	
10	40.9	46.7	2.9	0.4	9.3	New furnace here on
11	41.4	47.2	2.3	0.2	8.7	
12	41.9	47.2	2.3	0.3	6.5	Percentage MgO = 1.8

The furnace walls were rebuilt after test 9 and lined on the inside with a one-inch coating of silicon-carbide cement. It was found that the molten slag did not attack this lining and after five runs little if any corrosion was evident.

The phosphate furnace slag was composed principally of lath-shaped crystals of pseudowollastonite ($CaO \cdot SiO_2$) (see Fig. 11). Between these crystals were small amounts of glass and dendritic crystals of cristobalite (SiO_2) (see Fig. 12). The pseudowollastonite tended to be either uniaxial plus or biaxial plus with a small $2V$ angle of 5°. The low index was close to 1.60, while the high

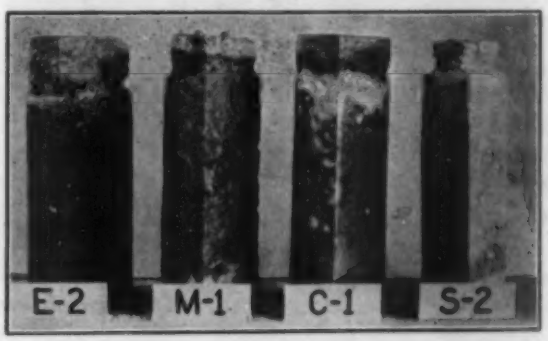

FIG. 6.—Refractory specimens after corrosion test, class 1.

was close to 1.65. These properties agree closely with those given by Winchell.[4]

(2) Refractories

A careful analysis of the results of the corrosion test made in the manner described, using phosphate furnace slag, places these brick roughly into six classes or types. The first five classes, arranged in descending order of their resistance to slag attack, are shown in Figs. 6 to 10 with the best brick in class 1 shown in Fig. 6. The class 6 brick are not illustrated. To simplify the discussion of the results, each class will be taken up separately.

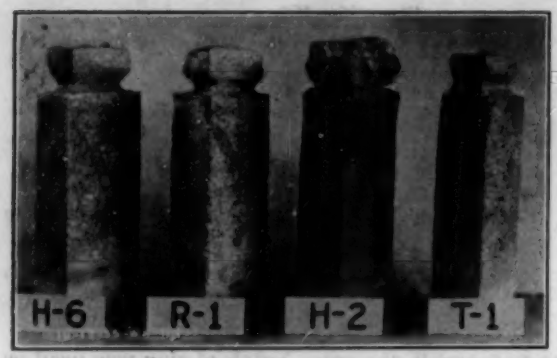

FIG. 7.—Refractory specimens after corrosion test, class 2.

Class 1: The four class 1 brick shown in Fig. 6 gave the best resistance to slag corrosion of the twenty-two brands tested. These brick vary widely both in physical and chemical properties as shown in Tables I and II; C-1 is a silicon-carbide refractory, E-2 a magnesite refractory, M-1 an electrocast mullite refractory, and S-2 a silica refractory. As can be seen from Table III, the silicon-carbide brick gave the best results* followed by the magnesite brick, the electrocast mullite refractory, and the silica brick. The silicon-carbide brick showed a very small volume loss and a small gain in weight owing to the absorption of slag into the pores of the brick. Brick C-1 showed slight evidence of attack at the flux line and the original corners of the test specimen were still fairly sharp and showed practically no corrosion.

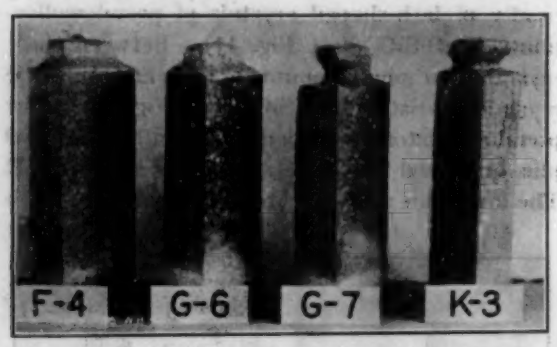

FIG. 8.—Refractory specimens after corrosion test, class 3.

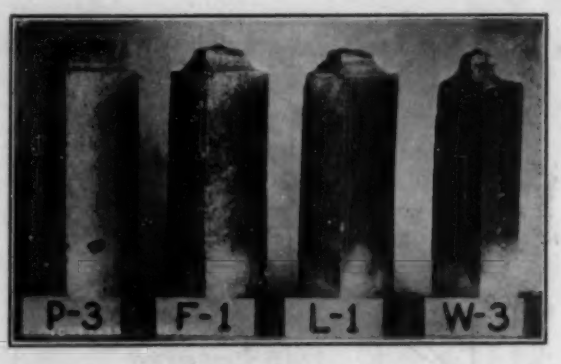

FIG. 9.—Refractory specimens after corrosion test, class 4.

Magnesite brick E-2 showed an average volume loss of 9.8% and an average gain in weight of 21.5%. This brick was quite porous and tended to absorb a large amount of molten slag, apparently without attacking the brick structure. Duplicate runs of this refractory checked very well. This refractory had poor tensile strength at 1450°C and, as a result, had a tendency to part at the slag line during the tapping. The specimen shown in Fig. 6 had a shallow flux line with

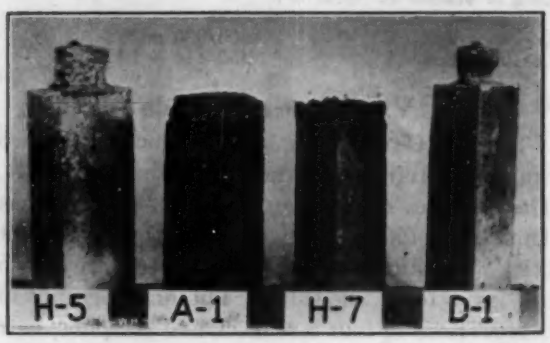

FIG. 10.—Refractory specimens after corrosion test, class 5.

[4] A. N. Winchell, Microscopic Character of Artificial Minerals. John Wiley & Sons, 1931.

* Later experiments in which the furnace slag was melted in a Detroit rocking-type furnace showed the silicon carbide to be an unsatisfactory lining under strongly reducing conditions. The SiC reduced the P_2O_5 in the slag with a consequent disintegration of the refractory.

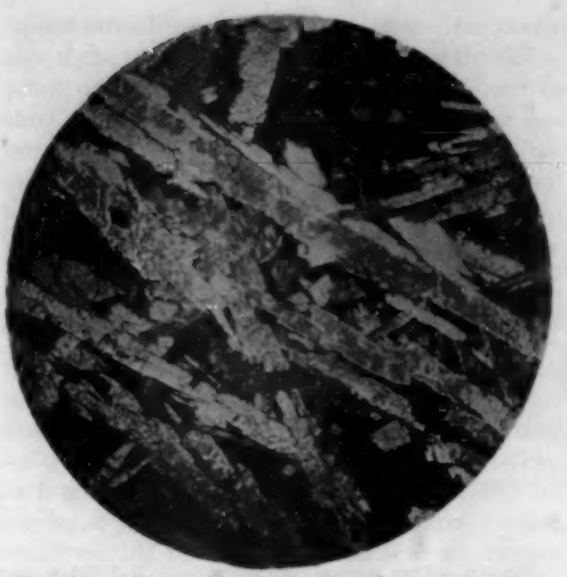

FIG. 11.—Thin section of phosphate furnace slag showing lath-shaped crystals of pseudowollastonite; black areas are glass; 25×, with crossed nicols.

slightly rounded corners. The amount of corrosion below the slag line was small.

The microscopic thin section of magnesite brick E-2 taken above the slag line, as shown in Fig. 13, consisted of rounded grains of sintered magnesite imbedded in a matrix of forsterite ($2MgO \cdot SiO_2$). The forsterite was found to be biaxial plus and had a high birefringence. The low index was close to 1.63 and the high index was between 1.66 and 1.67. The powdered material

FIG. 12.—Thin section of phosphate furnace slag showing dendritic crystals of cristobalite and enlarged pseudowollastonite crystals; 200×, with nicols at 75°.

showed small isotropic grains of periclase (MgO) and a small amount of glass.

The other section of this brick taken below the

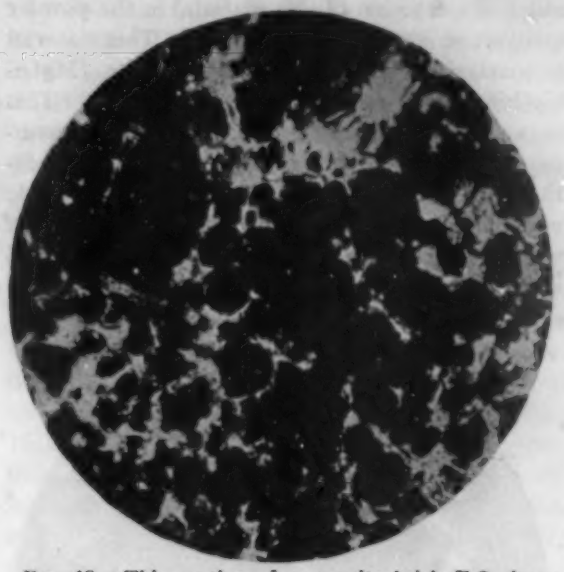

FIG. 13.—Thin section of magnesite brick E-2 above slag line; rounded grains are sintered magnesite; white material is forsterite; 250×, with crossed nicols.

slag line showed four distinct phases. Periclase was present in the rounded grains of sintered magnesite bonded by forsterite. The forsterite

FIG. 14.—Thin section of magnesite brick E-2 below slag line; *A* indicates akermanite; *B*, monticellite with some forsterite between rounded magnesite grains; 250×, crossed nicols.

was present only where the slag had not penetrated between the grains. This is shown in the upper half of Fig. 14. Akermanite ($MgO \cdot 2CaO \cdot$-

$2SiO_2$) was found around the outside edges of the section. It gave a uniaxial plus figure. The birefringence was low. It was difficult to get the index of refraction of this material in the powder analysis on account of its scarcity. This material is marked *A* in Fig. 14. Monticellite ($MgO \cdot CaO \cdot SiO_2$) was present in large quantities. This material had a higher birefringence than akermanite. It was found to be biaxial plus in some sections and biaxial minus in others. The $2V$ angle was estimated to be close to 90°. The low index was determined as 1.64 and the high index as 1.65 to 1.66. According to Winchell,[4] monticellite

FIG. 15.—Thin section of silica brick S-2 below slag line; wedge-shaped crystals of tridymite; light material slag; 350×, crossed nicols.

will be positive or negative, depending upon the character of solution taking place. This material is marked *B* in Fig. 14.

What takes place when the molten phosphate furnace slag comes into contact with the magnesite brick can best be explained by studying the three-component diagrams, $CaO–MgO–SiO_2$.[5] The molten slag is first absorbed by the brick and then takes into the solution some of the MgO, forming akermanite. As the temperature increases during the heating up, a eutectic liquid is formed at the interface between the pseudowollastonite and akermanite. This liquid starts to melt at approximately 1405°C. The slag that has penetrated the interior of the magnesite brick will not be washed away by the molten slag and will dissolve more MgO as the temperature is raised, eventually forming monticellite. The eutectic liquid formed between the molten slag and monticellite at the surface of contact at the higher temperatures (1450°C) possibly has the composition of point 8 shown on the $CaO–MgO–SiO_2$ diagram.[5] This eutectic has a melting point of approximately 1436°C. Apparently then, the magnesite brick

FIG. 16.—Thin section of mullite brick R-1 below slag line; tabular crystals of anorthite on left; fine mullite needles on right; 350×, crossed nicols.

FIG. 17.—Thin section of fire brick H-5 below slag line; upper half shows mullite needles crystallized in glass; lower half, calcined clay body with quartz grains; 350×, nicols uncrossed.

[5] F. P. Hall and Herbert Insley, "Compilation of Phase-Rule Diagrams," *Jour. Amer. Ceram. Soc.*, **16** [10] 520 (1933).

would probably withstand phosphate slag corrosion if the temperature were held below the fusion point of the eutectic. The slag test seemed to show that even at 1450°C the disintegration was not severe, probably owing to the fact that the amount of liquid formed even at 1450°C was not large, depending a great deal on the surface exposed to the reaction.

The average weight and volume losses of mullite brick M-1 were 30.4 and 31.7%, respectively. This brick showed practically no slag absorption, which was to be expected from the dense compact structure of this type of refractory. Some care had to be exercised in heating this refractory as it tended to crack if heated too rapidly. The surface of the immersed end was smooth but irregular, owing to small bubbles and pipes formed in the casting process. The flux line was deeper than that of the silicon carbide or magnesite brick and there was appreciable corrosion below the flux line. No thin sections were made of this brick.

The S-2 or silica refractory showed the most erratic results of any of the brick tested. The results of test on the three brick given in Table II indicated wide variation, although specimens S-1 and S-3 showed some agreement. From observations, it appeared that the results were greatly affected by the heating-up schedule and the temperature at which the slag first came into contact with the refractory. It was found that those brick that absorbed the most slag gave the least volume loss. This was shown by the gain in weight of brick S-1 and S-3 given in Table II. An examination of the temperature record showed that the silica brick tested in tests 9 and 14 were not held to as high a temperature during the charging period as in test 13. The slag was probably less viscous and more active at this higher temperature with the consequent result that the brick eroded away as fast as the slag penetrated. The corroded end of S-2 shown in Fig. 6 had a deeper flux line than the other three test specimens of class 1. The dimensions of the immersed end were reduced in all directions. The surface was rough and badly pitted. The silica test brick usually had fine cracks across the surface when removed from the test furnace. This, no doubt, was due to the inversion of the quartz during the cooling or heating period. No trouble was encountered, however, as a result of the spalling of the test specimen.

Two thin sections were made of the silica brick S-2, but owing to the slight differences between these sections, a photomicrograph was made only of the section taken below the slag line, as shown in Fig. 15. The section above the slag line showed an abundance of well-formed wedge-shaped twins of tridymite (SiO_2) in a light yellow-green glass between the larger unconverted quartzite grains. The margins of some of the original quartzite grains were defined by fine tridymite crystals. The section taken below the slag line was similar to the one taken above, except for the presence of a large amount of crystalline slag that had penetrated the interstices between wedge-shaped twins of tridymite and some unconverted quartzite grains. A well-formed wedge-shaped twin of tridymite is shown on the right-hand side of Fig. 15. The white material is slag that has crystallized as pseudowollastonite. The slag apparently had penetrated the porous structure of the silica brick without reacting appreciably with the tridymite.

If the two-component diagram of the system CaO–SiO_2[6] is examined, an explanation can probably be given as to what takes place when molten phosphate slag comes into contact with a silica brick. This diagram shows that the lowest melting liquid formed between pseudowollastonite or α-$CaO{\cdot}SiO_2$ and tridymite takes place at approximately 1436°C. Small amounts of impurities in the slag such as Al_2O_3, Fe_2O_3, or P_2O_5 would probably lower this melting point somewhat. This liquid would form at the surface of contact between the molten slag and the silica brick and tend to dissolve the structure. The rate of disintegration would depend a great deal upon the temperature and viscosity of the liquid, the amount of brick surface exposed, and the rate at which the molten slag was renewed at the surface. If the temperature was maintained below 1436°C, there would apparently be little liquid formed and consequently little attack on the brick. The slag penetrating the brick would not be diluted or washed away easily, but would take tridymite or SiO_2 into solution, forming liquid B. At 1450°C liquid B would soon become saturated with respect to SiO_2 and further action would cease. The amount of liquid formed in the pores at a given temperature will depend upon the relative amounts of slag and SiO_2 present.

[6] F. P. Hall and Herbert Insley, *loc. cit.*, p. 492 (Fig. 37).

Class 2: The brick of class 2 shown in Fig. 7 comprise a magnesite brick, a fireclay brick, and two mullite brick. The mullite brick were manufactured from Indian kyanite.

Specimen H-2 is a magnesite refractory of a different brand of manufacture from E-2 described in class 1. This brick apparently stood the slag erosion satisfactorily, but during the tapping of the slag the end dropped off owing to poor tensile strength. After the furnace had cooled, the end was recovered and a rough determination of the weight loss made. The 13.7% gain in weight showed that the brick absorbed considerable slag. It is believed that a denser brick made of the same material and fired to a higher temperature would have given better results. There are indications that a brick of this type would resist phosphate furnace slag attack equal to any brick of class 2 if it were well supported and free of tensile stresses.

A thin section of mullite brick R-1 was made below the slag line and a photomicrograph of a portion of this section is shown in Fig. 16. The general structure of the brick is a mass of fine aggregates of mullite needles, shown on the right side of Fig. 16. Where the slag had penetrated the brick, it apparently had reacted with the mullite to form anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$) and a light yellow-green glass, shown on the left side of Fig. 16. The lath-shaped anorthite crystals gave a biaxial-interference figure with a $2V$ angle of about 75°. The crystals showed twinning and gave a medium birefringence. The β-index determined on the powder was close to 1.58. There were also indications of small quantities of gehlenite ($2CaO \cdot Al_2O_3 \cdot SiO_2$) with an index of refraction close to 1.64. Gehlenite, however, could not be found in the thin section.

The three-component diagram, CaO–Al_2O_3–SiO_2,[7] serves to explain what probably took place when the molten slag came into contact with the mullite brick. Since the three phases identified by the microscope are α-$CaO \cdot SiO_2$, $CaO \cdot Al_2O_3 \cdot 2SiO_2$, and $2CaO \cdot Al_2O_3 \cdot SiO_2$, it is reasonable to believe that the eutectic glass formed by the attack on the brick would have a composition close to that of point 5 on the diagram. This glass melts at 1265°C, and at 1450°C would probably be very active chemically in disintegrating the brick. This would serve to explain why the mullite brick did not stand up as well as the silica or magnesite brick in the slag test.

Class 3: Brick of class 3 (shown in Fig. 8) include a glass refractory, a fire brick, a diaspore fire brick, and a kaolin fire brick. Table II shows that these brick varied widely in physical properties. This class of test brick showed approximately 10% greater volume and weight losses than class 2. The average weight loss was 65.2%. There was not a great deal of difference between the four brands of brick, but specimen G-6 showed a slightly lower volume loss and specimen K-3 a slightly smaller weight loss. None of the test specimens showed any marked tendency to absorb molten slag. The flux lines for these brick were quite deep and irregular, varying from $^5/_8$ to $^7/_8$ inch in depth. The immersed end in every case showed slag attack on all sides. The eroded surface of F-4 was much smoother than the other three. The other specimens had fairly rough surfaces with numerous pieces of coarse grog projecting from the surface. The brick of this class with the lower porosities tended to give a more even slag line and slightly better resistance to slag attack. There was no apparent relation between the corrosion losses and the composition or refractoriness of the brick.

Class 4: Four test brick are shown in Fig. 9 for class 4. Test brick W-3 was included in this photograph for convenience, but it really belongs to class 5. F-1, L-1, and P-3 were commercial types of glass refractories or flux block. The average weight and volume losses for this class of brick were 75.6% and 91.4%, respectively. All three brick, F-1, L-1, and P-3, had smooth surfaces of attack with deep flux lines varying from $^{15}/_{16}$ to 1 inch in depth. These brick also showed appreciable corrosion on the extreme ends. There was very little, if any, slag absorption. It will be noted that brick F-1 and L-1 showed much higher volume losses than weight losses. This was due to the fact that the hot end of the brick actually shrank during the test. Both brick also had a tendency to develop horizontal cracks during the test. The only explanation that can be offered is that the bodies of these brick contained appreciable quantities of free quartz. Brick P-3, on the other hand, showed good agreement between weight and volume losses and gave the best results for the class 4 brick.

Class 5: The class 5 test brick (Figs. 9 and 10)

[7] F. P. Hall and Herbert Insley, *loc. cit.*, p. 524 (Fig. 92).

showed a wide variation in physical and chemical properties. A-1 was a chrome brick and H-7 a forsterite refractory. The other three test brick, D-1, H-5, and W-3, were second-grade fire brick. The average weight loss in the corrosion test for this class of brick was 79.1%, while the average volume loss was 95.0%. The immersed ends of specimens A-1 and H-7 were completely corroded away during the test. Theoretically, the weight losses for these two brick should be 100%, but these brick absorbed enough of the molten slag to give lower apparent values. In cases such as this, the volume loss is a more accurate measurement of the resistance to corrosion than the weight loss.

The weight and volume losses for brick D-1, H-5, and W-3 were nearly identical, with H-5 showing the best results. These three brick showed no evidence of slag absorption. As can be seen from Fig. 10, the slag lines were sharp and well defined and varied in depth from $1^1/_8$ to $1^1/_4$ inches. The corroded surfaces of D-1 and H-5 were rough and pitted, while W-3 had a comparatively smooth surface. None of the brick of this class would be satisfactory in resisting phosphate furnace slag attack at 1450°C.

A thin section of brick H-5 made below the slag line is shown in Fig. 17. The lower part of the photomicrograph shows a high quartz clay body with considerable glass present. The upper part shows the contact surface between slag and refractory, which consists of small needle-shaped crystals imbedded in a glass of refractive index 1.55 to 1.56. These needles show parallel extinction, positive elongation, and an index of refraction greater than 1.56. In the powder analysis, the needles appeared to have an index higher than 1.64. From this evidence it is believed that the needles were mullite that probably crystallized out in the glass adhering to the refractory during the cooling. The fact that this brick had a much higher silica content and gave a higher corrosion loss than the mullite brick would lead one to believe that the eutectic glass formed between the slag and the brick was probably of a lower melting point. If the CaO–Al_2O_3–SiO_2 diagram[7] is referred to, it will be found that there is a eutectic formed between α-$CaO{\cdot}SiO_2$, $CaO{\cdot}Al_2O_3{\cdot}2SiO_2$, and tridymite ($SiO_2$) at point 2 with a fusion point of 1170°C. This would explain the difference in slag resistance between this brick and the more highly aluminous varieties.

Class 6: The brick of class 6 were those refractories that spalled during the test. The spalling in every case did not take place during the heating period, but during the charging of the cold slag. Two runs were made using brick B-1 and B-2, but with no success. Smaller charges of slag were used in testing B-2, but it broke off above the slag line before the test was completed. Refractory L-5 acted in the same manner. These two brick were typical high silica-glass refractories and the spalling or cracking may possibly be due to a high free quartz content. The chemical analyses of brick B-1 and L-5 given in Table III showed these brick to contain 64.7 and 67.7% SiO_2, respectively. The silica content was not as high as that of specimen L-1 given in class 4, but the form in which the SiO_2 was present in the body seemed to be of great importance.

Another explanation for the above behavior might be that brick B-1 and L-5 failed in tension owing to the failure of the bond at high temperatures. An examination of the pieces of these brick after test, however, would lead to the belief that the former explanation was the correct one.

VII. Conclusions

(1) Quantitative, reproducible measurements of molten slag attack can be made upon various types of refractories by this method of testing.

(2) The silicon-carbide brick gave the best results of the twenty-two brands of brick tested, while the silica brick gave results showing the greatest variation.

(3) Magnesite brick tested by this means tended to break off at the slag line due to slag absorption and to poor tensile strength.

(4) Acid and basic refractories resisted molten phosphate slag attack quite well.

(5) In refractories of varying silica and alumina content, the refractoriness did not seem to be as important as the density and body structure in resisting phosphate slag corrosion.

(6) The chemical composition of a refractory is important in resisting slag corrosion when the porosity is high. The porosity of a refractory is important in resisting slag corrosion when the composition is not suitable to resist chemical attack.

(7) Refractories which spall easily are difficult to test by this means.

(8) The volume loss of a refractory is a better measure of the degree of slag attack than the

weight loss if the refractory absorbs a large amount of slag.

(9) Petrographic studies of the zones of contact between test brick and slag serve to explain why certain types of brick resisted the slag attack better than others.

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* These are additional references to the footnote references given in the text of this paper.

Fertilizer Works
Tennessee Valley Authority
Wilson Dam, Alabama

QUARTZ AS A DEVITRIFICATION PRODUCT OF VITREOUS SILICA*

By L. J. Trostel

Abstract

Quartz has been observed as a devitrification product of vitreous silica prepared from glass sand when heated for four hours at 1300°C. Another type of commercial vitreous silica did not devitrify under the same conditions. Examination of the various properties of the two samples of vitreous silica by means of the microscope, interferometer, and X-ray did not disclose differences which would explain the cause of the devitrification. Several theories are advanced to explain the phenomena observed.

I. Introduction

In an investigation involving inversions of various quartzites, it was noted that under certain conditions quartz appeared as a devitrification product of vitreous silica.

The phenomenon can be anticipated from Fenner's[1] vapor-pressure curve for the various modifications of silica (see Fig. 1), but there appears to be no recorded experience of the fact. Sosman,[2] for instance, states, "above 870° quartz has never been produced from vitreous silica either directly or indirectly."

Fenner's diagram, intended to illustrate the stability ranges of the various forms of silica, shows the relative position of the curves of vapor pressure plotted against temperature for each modification. The curves are based on the thermodynamic principle that the stable modification of silica at a given temperature has the lowest vapor pressure, although the actual vapor pressures are unknown and very small.

At some selected temperature and pressure, one phase will be found which is more stable than any of the others, and all of the others present will in time change to this most stable modification. For instance at 1300°, the most stable phase is tridymite, though both quartz and cristobalite may exist as metastable phases. In the present work both of these metastable phases were observed by heating at 1300°. At 1400°, no quartz is to be expected and none was observed.

A vitreous silica prepared from Ottawa glass sand and a commercial form of transparent vitreous silica were each given the particular devitrification treatment described later. Only the former devitrified to produce quartz.

Because of the novelty of this direct experimental evidence of the formation of quartz by devitrification, it has been made the subject of this paper.

II. Preparation of the Vitreous Silica from Glass Sand

The sand was first ground to pass a 100-mesh sieve and formed into cones about $2^1/_2$ inches high with a $^5/_8$-inch base. These were introduced into a P.C.E. furnace previously brought up to a temperature of about 1760°C by means of an oxyacetylene flame. The sand cones melted completely to a nearly clear glass in 10 minutes. There were some air bubbles present, but not enough to make the glass opaque.

III. Devitrification Treatment

The vitreous silica in each case was crushed and the grains were used which passed a 6-mesh sieve and were retained on a 20-mesh sieve. The grains were wrapped in platinum foil and introduced into a quenching furnace previously brought up to 1300°C, held at this temperature for 4 hours, then withdrawn and water-quenched.

IV. Identification of Phases Present after the Devitrification Treatment

Examination of the fused glass sand, after the heating to 1300°, indicated the presence of an appreciable amount of quartz mixed with residual glass. The quartz crystals could be located easily when viewed with crossed nicols because of their distinct double refraction.

This secondary quartz occurred in the glass as rounded, irregular, or anhedral-shaped inclusions, varying in diameter from 0.0036 to 0.0180 millimeter, in contrast to the ground quartz from the original sand existing before fusing as coarse crystals of about 0.147 millimeter in diameter. The mean index of refraction of the secondary quartz determined on edges of fragments from which the glass had broken away was 1.550. It

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, March 31, 1936 (Refractories Division). Received April 16, 1936.

[1] C. N. Fenner, "The Stability Relations of the Silica Minerals," *Amer. Jour. Sci.*, **36**, 331–84 (1913).

[2] R. B. Sosman, The Properties of Silica, p. 105. The Chemical Catalog Co., Inc., 1927.

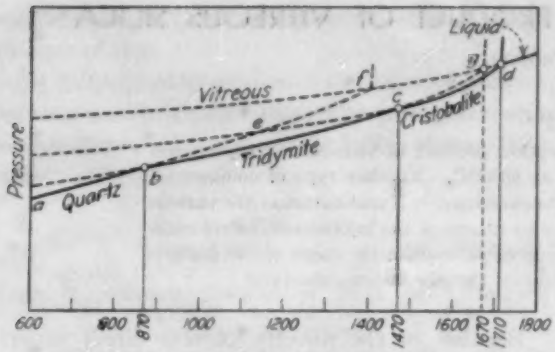

FIG. 1.—Imaginary vapor-pressure curves of the principal forms of silica; *ab*, upper part of stability range of quartz; *bc*, stability range of tridymite; *cd*, stability range of cristobalite; *e*, metastable inversion point of quartz and cristobalite (temperature unknown); *f*, melting point of quartz (temperature not exactly known); *g*, metastable melting point of tridymite.

was impossible to measure the index on many of the quartz grains because they were surrounded by the glass. It was apparent, however, that the index of refraction of the inclusions was considerably higher than that of the enclosing glass.

The commercial transparent vitreous silica, when given the identical treatment as for the fused glass sand, remained practically undevitrified. Only a slight cloudiness could be observed on the surfaces of the grains, and the microscope showed only vitreous silica.

Because of the difference in behavior of the two glasses, it was thought that possibly the fused sand may have contained residual quartz as nuclei too small to be identified even at fairly high magnifications. To determine whether or not this was the case, thermal expansion measurements were taken by means of the sensitive interferometer method on the fused glass sand as made and after the devitrification treatment.

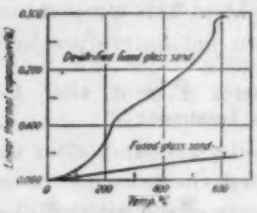

FIG. 2.—Expansion characteristics of fused glass sand before and after devitrification.

Curves plotted from the data are shown in Fig. 2.

It will be noted that the expansion of the glass, as made, is very low and no inflections are evident at the inversion temperatures of the several allotropic forms of silica. Furthermore, the mean linear coefficient of expansion of the glass from 25° to 655°C was found to be 0.00000068. This compares favorably with a mean value of about 0.00000055 calculated from the curves shown by Sosman,[3] in which he plotted the mean coefficient of linear expansion from 0° to 1100° from the experimental data of a number of investigators.

The expansion curve for the devitrified fused glass sand, however, shows positively the presence of quartz, substantiating the appearance under the microscope. Cristobalite is also present, based on the change in slope of the curve starting about 155° and continuing to 230°C. The general contour of the curve above 230°C and particularly the sharp inflection at 570° to 575°C is an indication of the presence of quartz. The generally suppressed level of the curve indicates that the mixture is still high in residual glass content.

V. X-Ray Patterns of Materials

Inasmuch as no evidence could be found of differences in the two vitreous silica specimens from an examination of the optical properties or thermal expansion characteristics, it was felt that an examination of the X-ray patterns might possibly disclose some characteristic difference.

Through the courtesy of Sosman and Warren, X-ray patterns were obtained of the two vitreous silica samples as well as of the specimen which devitrified.

Sosman's patterns were obtained by photographing the powder, suspended in about one-fifth of its weight of Duco cement, and by using a rounded edge of the hardened mixture as the source of diffraction. The radius of the film was 114½ millimeters, corresponding to 2 millimeters for one degree angle. The source of the X-rays was a water-cooled Coolidge tube with molybdenum target, and the exposure was 20 hours at 21 milliamperes.

The two vitreous specimens gave identical patterns, namely the diffuse banding which is characteristic of liquids and glasses with no indications of the lines characteristic of a crystalline substance. Two fairly strong bands are evident and two very faint ones, corresponding roughly with the more intense lines of quartz. Sosman has suggested that very small crystal nuclei, perhaps only a few atomic radii in diameter but uniformly dispersed through the glass, would have just this effect of producing a set of bands. Such nuclei would have to be present to a considerable per-

[3] R. B. Sosman, Properties of Silica, p. 400.

centage, such as 10 or 20%, before they would begin to produce definite lines. On this evidence alone, it is not safe to say that quartz nuclei are present in the vitreous silica. An important point, furthermore, is that the patterns are not visibly different.

Earlier patterns of vitreous silica, as described by Warren,[4] consist of a single band. This, as explained by Warren, is due to the fact that his early work was done with Cu-radiation, the idea being that the longer wave-length spread the pattern out more and allowed more precise measurement of the peak positions. With Mo-radiation, however, several more peaks show up as observed in the patterns obtained by Sosman.

FIG. 3.—Comparison of structures of vitreous silica specimens.

Warren's patterns of the two vitreous silica samples were made with CuKα-radiation monochromatized by reflection from rock salt in an evacuated camera of radius 4.40 centimeters. The Cu-radiation spreads the pattern and gives the strong ring of quartz, if present, an opportunity to show. There are, of course, additional fainter rings at a larger angle which do not show here because Cu-radiation was used with the transmission method.

The patterns of both vitreous silica samples again appear the same, as shown in Fig. 3, and microphotometer records do not show any definite difference.

The patterns of the two vitreous silica samples, therefore, indicate no difference in structure between the two glasses. Quartz, as a residual material after fusion, either was absent in both samples or the fundamental structure of the original crystalline quartz was not completely destroyed on melting in the case of the fused glass sand, and nuclei too small to be called crystalline nuclei persist in the liquid. Sosman suggests that these nuclei might be present as a kind of colloidal suspension of atomic groups, comparable in size to molecules, and consequently might serve as nuclei for crystalline growth without being large enough to give any evidence of their existence by X-ray diffraction.

The X-ray patterns, however, obtained for the partially devitrified fused sand by Sosman and Warren, show the pattern of quartz plainly and that of cristobalite faintly and confirm the writer's observations of the partial devitrification of the fused sand. The pattern obtained by Warren for the partially devitrified glass is shown in Fig. 4 with patterns of pure quartz and cristobalite for comparison.

VI. Explanation of Phenomena Observed

Thermodynamic and phase-rule theory assume that the properties of materials depend only on temperature and pressure and not on past history. The phenomena observed here, however, of two apparently similar samples of vitreous silica devitrifying differently, one to produce quartz and the other not, tend to point out that the past history of the substances must be of importance. Sosman[5] thinks that both the mechanical and thermal aspects of this past history should be considered.

The vitreous silica from glass sand, as described previously, was made by heating only 10 minutes and air-quenching. No subsequent casting, drawing, or molding took place to disturb the structure produced. It is conceivable that, while most of the sample had been converted quickly to glass by direct melting of the quartz which starts at about 1400°, a certain percentage might persist in the liquid after fusion as superheated quartz. This would be present as extremely minute nuclei whose structure would require both

[4] B. E. Warren, "X-Ray Determination of the Structure of Glass," *Jour. Amer. Ceram. Soc.*, **17** [8] 249–54 (1934).

[5] R. B. Sosman, The Properties of Silica, pp. 254–55.

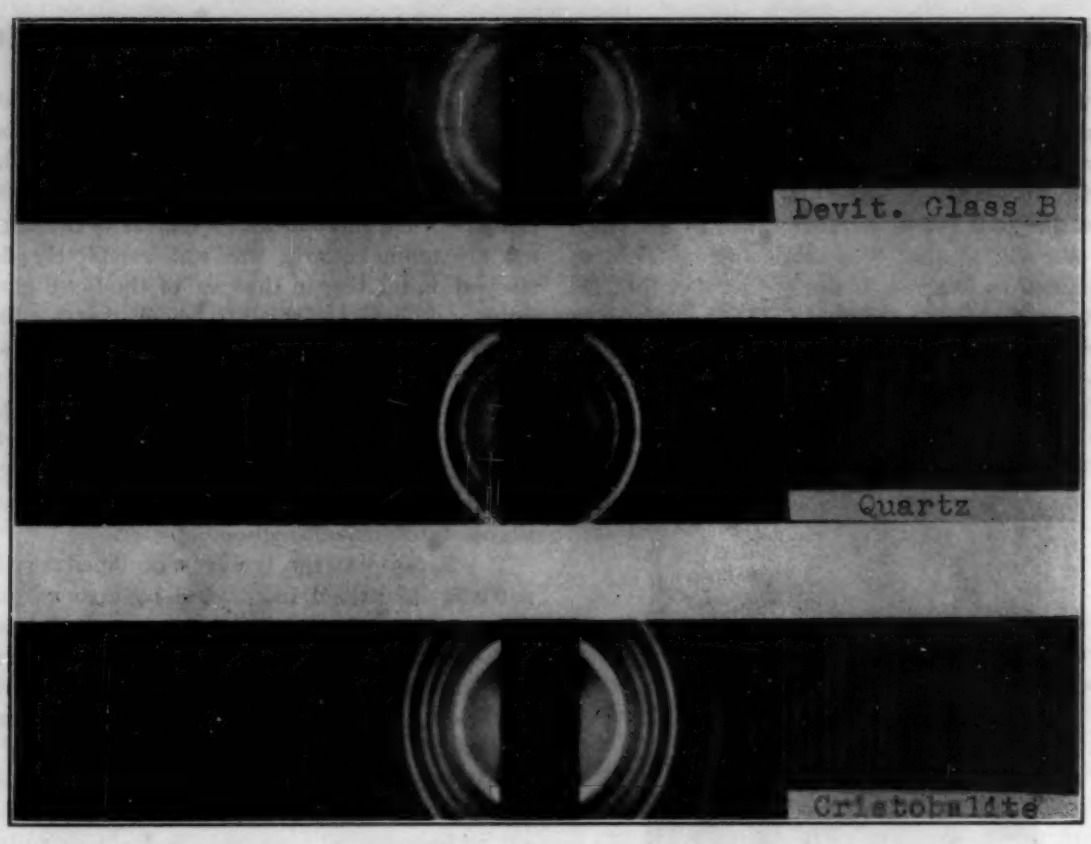

FIG. 4.—Comparison of structure of vitreous silica from glass sand after heating with quartz and cristobalite.

time and excess temperature to destroy. The amount and size of such nuclei may be so small that they do not diffract the X-ray and thus have no effect on the general pattern.

This superheated quartz would be under strain, and subsequent heating, such as was employed in the devitrification treatment, might result in the release of this strain by recrystallization about the residual nuclei to produce crystals large enough to be seen with the microscope and cause the decided inflection observed in the expansion curve at the α- to β-quartz change at 573°C.

The commercial transparent vitreous silica used for comparison is made from a pure form of rock crystal by fusing for a considerable period of time at about 2200°C in an electric resistance furnace. The material is then worked or drawn into particular shapes.[6] Part of a transparent crucible was used in this investigation. Since the time of heating was much longer than the 10 minutes used by the writer, and the temperature was about 400°C higher, coupled with after-working, it is possible that this product may be melted cristobalite. It would accordingly contain no residual quartz under strain due to superheating.

It has been suggested that the theory of Buerger[7] is of interest in this connection. This theory states that the high temperature forms of silica, tridymite, and cristobalite differ from quartz chiefly in having a very open structure dynamically maintained at the high temperatures by thermal agitation. This open structure may be statically maintained at lower temperatures by the presence of foreign ions which, filling the voids, prevent repacking to the closer structure of quartz.

If it may be assumed that vitreous silica, another high-temperature form of silica, also has a very open structure, this may be maintained, *i.e.*, it does not devitrify if foreign ions are present to prevent repacking at least to quartz at low temperatures. This hypothesis would permit the conclusion that the commercial vitreous silica

[6] Private communication.

[7] M. J. Buerger, "Silica Framework Crystals and Their Stability Fields," *Z. Krist.*, 90, 186–92 (1935); *Ceram. Abs.*, 15 [1] 24 (1936).

contains foreign ions either as the result of the origin of the rock crystal used or the method of preparation in the electric furnace. The vitreous silica on the other hand, prepared from domestic glass sand by heating in an oxyacetylene flame, would be assumed to be free from the inhibiting influence of foreign ions.

CHEMICAL COMPOSITION OF VITREOUS SILICA SAMPLES

	From glass sand	Commercial specimen
SiO_2	99.28	99.30
Fe_2O_3	0.20	0.20
Al_2O_3	0.28	0.28
TiO_2	Trace	Trace
CaO	0.04	0.04
MgO	0.08	0.09

The amount of the foreign ions which may be effective is shown in Buerger's work to be as low as 2.5% in a sample of natural tridymite and as high as 9% in a sample of natural cristobalite. Chemical analyses of the two vitreous silica samples are shown below. Apparently the materials are very pure and nearly identical. The analyses point out that the inhibiting effect of foreign ions is not the explanation for the difference in devitrifying behavior.

No conclusions supported by direct experimental evidence, therefore, can be drawn to explain the cause of the devitrification of the fused glass sand, although the method of preparation of this particular glass appears to be the most likely cause. This method permits the continued existence of quartz nuclei, too small to diffract even the X-ray, and these nuclei act to direct the crystallization or devitrification.

Acknowledgment

The author is indebted to R. B. Sosman and B. E. Warren for their kindness in examining the various silica specimens with the X-ray and to Herbert Insley for checking the index of refraction of the quartz observed.

RESEARCH LABORATORY
GENERAL REFRACTORIES COMPANY
BALTIMORE, MARYLAND

A COMPARISON OF THE THERMAL EXPANSION OF USED SILICA BRICK FROM AN INSULATED AND AN UNINSULATED OPEN-HEARTH FURNACE ROOF*

By R. H. H. Pierce, Jr., and J. B. Austin

Abstract

Measurements of the linear thermal expansion of different zones in the used silica roof brick whose composition and structure have been described by Harvey show that along the length of the brick there are two abrupt changes in expansion. The first, whose existence was predicted by Harvey and by Miller, coincides with the limit of penetration of iron oxide and arises from the fact that in the presence of iron oxide the silica, originally present as cristobalite, has been largely converted to tridymite, which has a different expansion. The limit of penetration of iron oxide is taken as that level at which the average temperature is 1100°C (2010°F), the temperature of the ternary eutectic in the system CaO–FeO–SiO_2; consequently, the abrupt change in expansion, and therefore a zone of weakness, is to be expected after equilibrium has been estab lished in any open-hearth roof brick whose cold end is below 1100°C (2010°F). The second change, which is also due to a discontinuity in the distribution of cristobalite, occurs at that level in the brick at which the average temperature was 1470°C (2680°F), the lower limit of the stable range for cristobalite. In each case the change in expansion arises directly from a difference in the length-change at the cristobalite inversion, which takes place at approximately 250°C (480°F), so that failure or spalling is most likely to occur when the roof is cooled below or heated through this temperature. The expansion data also show that the inversion temperature of cristobalite increases regularly with the temperature at which it was formed or at which it was brought to equilibrium.

The data obtained enable the determination of the average distribution of temperature through the brick in service, which, combined with existing data on thermal conductivity of silica brick, permits an estimation of the mean thermal conductivity of that part of the brick into which iron oxide has penetrated.. This conductivity is greater than that of the rest of the brick and has a negative temperature coefficient in contrast to the positive coefficient for the unaltered part.

I. Introduction

In a recent comparison of used silica brick taken from the roofs of two basic open-hearth furnaces, one insulated, the other not, Harvey[1] reported that the brick from the uninsulated roof showed nine distinct color zones, whereas the other showed but three, which, however, had the same composition and structure, zone for zone, as the corresponding zones at the hot end of the uninsulated brick. He expressed a belief that the level at which breakage of roof brick so often occurs in service coincides with the position of zones 4 to 7 (counting from the hot end); consequently, it is present in the uninsulated but not in the insulated roof. The chemical and petrographic analyses of the several zones failed to give any certain indication why such a zone of weakness should exist. Harvey, however, pointed out that logically there should be an abrupt change in the expansion of the zones, either between 3 and 4 or somewhere between 4 and 7, and suggested that measurements of the expansion of the several zones would aid in interpreting the behavior of these brick.

A somewhat similar study of brick from an insulated and an uninsulated open-hearth roof has also been made by Miller.[2] His conclusions, based chiefly on examination of thin sections, are in general in agreement with Harvey's, the chief difference being that Miller differentiates but three zones in each brick, whereas Harvey considers three in the insulated and nine in the uninsulated roof. Miller's zone A, the cristobalite-rich zone at the hot end, corresponds to Harvey's zone 1; Miller's zone B, classified as the tridymite-rich middle section, covers Harvey's zones 2 to 4, inclusive; and Miller's zone C, which is at the cool end of the brick, corresponds to Harvey's zones 5 to 9, inclusive. Miller reports cracks between zones B and C which, in agreement with Harvey's conclusion, he interprets as due to a

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, March 31, 1936 (Refractories Division).

[1] F. A. Harvey, "Comparison of Used Silica Brick from Insulated and Uninsulated Basic Open-Hearth Roofs," *Jour. Amer. Ceram. Soc.*, **18** [3] 86–94 (1935).

[2] L. B. Miller, "Effect of Insulation on the Silica Refractories of an Open-Hearth Steel Furnace Roof," *Bull. Amer. Ceram. Soc.*, **14** [11] 359 (1935).

marked difference in thermal expansion at this point.

Only a few actual measurements of the expansion of different zones in a silica brick are available and these are not completely satisfactory. Travers and Goloubinoff[3] studied three sections cut from a used silica brick, and their results indicate a change in the character of the expansion from zone to zone, but no description of the brick is given so that their data are difficult to interpret. The expansion of four different sections of a roof brick which had been in service for 12 weeks has been reported by Houldsworth and Cobb; but as their specimens were relatively large, their results do not yield the desired information on the variation in expansion over a short distance. As the matter is of some importance in the operation of an open-hearth furnace, it seemed desirable to carry out Harvey's suggestion and to study it more thoroughly. The authors therefore have determined the linear thermal expansion of the several zones in the two brick studied by Harvey by means of the interferometric dilatometer employed in an earlier study of the expansion of different parts of used coke-oven brick,[4] which permits the use of specimens small enough to be cut from within a single zone.

II. Samples and Method of Measurement

To permit a direct comparison with his observations, Harvey supplied lengthwise sections of the two brick used in his studies. As a detailed description of these brick is given in his paper, nothing need be added here except that shortly after the appearance of his paper it was discovered that the original brick were 16-inch straights instead of 12-inch wedges as stated.

In preparing the specimens, a slab $^1/_4$-inch in thickness was cut from the length of each brick, after which sections $^1/_4$ inch in width were cut parallel to the color bands so that their position corresponded as closely as possible with those of the samples taken by Harvey for chemical and microscopic examination. The specimens for the dilatometer,[5] in the form of three small tetrahedra approximately 4 millimeters in altitude, were then ground from the sections representing each zone. For the narrow zones, 4, 5, 6, and 7, the height of the specimens was approximately the same as the thickness of the zone. Individual runs were made for each zone, excepting zone 8 of the uninsulated brick which, as far as could be judged from the chemical and petrographic data of Harvey, was identical in structure and composition with zone 9. Only one run was made for each section, and all observations were made during heating.

III. Results and Discussion

Before making the expansion measurements, the porosity and apparent specific gravity of each zone was determined by the standard method of displacing the air contained in the pores with water, with results given in Table I. These data

TABLE I

POROSITY OF ZONES OF BRICK AS DETERMINED BY DISPLACING AIR IN PORES WITH WATER

	Uninsulated brick		Insulated brick	
Zone	Apparent specific gravity	Porosity (%)	Apparent specific gravity	Porosity (%)
1	2.412	8.6	2.421	4.9
2	2.363	5.0	2.383	2.8
3	2.399	7.5	2.371	8.9
4	2.394	13.3		
5	2.350	24.2		
6	2.355	24.8		
7	2.353	24.7		
8	2.353	24.4		
9	2.358	24.6		

for each brick are shown graphically in Fig. 1, which also includes the results of the chemical analyses reported by Harvey. Comparison of the several curves in this figure suggests that there is a simple relation between the porosity of the zones and their content of iron calculated to Fe_2O_3, and a replotting of the data (Fig. 2) shows that such a relation, common to both brick, does exist. It was to be expected that the porosity would decrease with increasing content of iron oxide because of the greater amount of liquid present, but it is rather surprising that the points fall so well on a straight line. This correlation involves implicitly a variation in CaO content so that the interpretation is rather difficult, but it is interesting to note that extrapolation of this curve indicates that iron equivalent to 10% Fe_2O_3 gives zero porosity. There is no apparent correlation between porosity and CaO content.

[3] Travers and Goloubinoff, "Study of Silica Brick; Dilatometric Analysis; Testing of the Raw Materials," *Rev. Met.*, **23**, 27–47, 100–17(1926); *Ceram. Abs.*, **5** [8] 253 (1926).

[4] J. B. Austin and R. H. H. Pierce, Jr., "Constitution and Thermal Expansion of Silica Coke-Oven Brick after Service," *Jour. Amer. Ceram. Soc.*, **16** [2] 102–106 (1933).

[5] See J. B. Austin, "Thermal Expansion of Some Refractory Oxides," *ibid.*, **14** [11] 795–810 (1931).

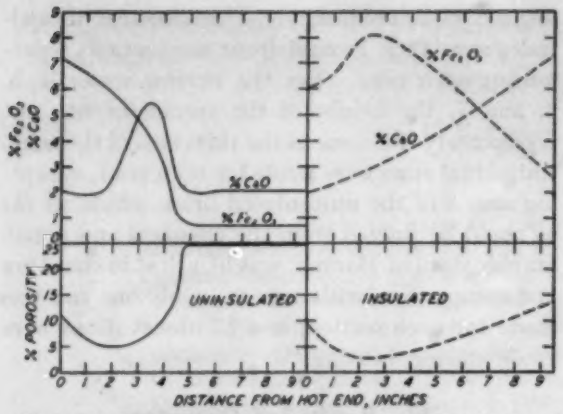

FIG. 1.—Curves showing the variation of content of Fe_2O_3 and CaO (taken from Harvey) and of porosity with position in the brick (solid lines for uninsulated brick; dashed lines for insulated brick).

On examining the face of the uninsulated brick from which the slab had been cut, it was observed that the silicon-carbide wheel had given it a fairly high polish so that by looking at it by reflected light at grazing incidence the change in texture at the limit of penetration of the iron oxide could be plainly seen. This change is also evident in Fig. 3, which shows an ink print made by inking the surface with a rubber roller. This upper limit of penetration also corresponds closely with the boundary between zones 4 and 5 (the boundary between zones B and C in Miller's brick).

(1) Thermal Expansion

The results of the thermal expansion measurements are given by the curves in Figs. 4(*a*) and 4(*b*), which show the increase in length of each zone (expressed in percentage of the length at 20°C) with increase in temperature over the range 20° to 600°C. (In these figures, as in the others, results for the insulated brick are given by dashed lines, those for the uninsulated brick by full lines.) The same data are plotted in Fig. 5 on a single set of coördinates for each brick, which method, although tending to obscure individual curves, serves to emphasize the difference between groups of curves.

The data show clearly, especially in Fig. 5, that there are two relatively abrupt changes in the magnitude of the total expansion, as one moves along the length of the brick; first, a marked change between zones 4 and 5 of the uninsulated brick as predicted by Harvey and by Miller; second, an almost equally large change between zones 1 and 2 (zones A and B in Miller's brick). For example, in the uninsulated brick the total expansion of zone 5 between 20°C and 300°C is greater than that of zone 4 by 0.42% of the length at 20°C, and the corresponding difference between zones 1 and 2 is of the same order of magnitude, being 0.25% (of the length at 20°C) for this brick and 0.44% for the insulated brick. Abrupt changes of this character, occurring over a small distance along the brick are sufficient to account for the failure of the brick in many cases. It would be interesting to calculate quantitatively the stress produced by such a difference in thermal expansion under different conditions as, for instance, a constant uniform temperature or a constant temperature gradient. The mathematics involved, however, is difficult and no reliable data on the mechanical properties of silica brick are available; consequently little can be said except that inasmuch as failures do occur in service the stresses must be relatively large. A determination of the deformation at the ultimate tensile, compressive, and shear stresses, and of the moduli of elasticity of a silica brick is greatly needed and should be a profitable field for research.

Although the change in character of the expansion of adjacent zones provides a satisfactory explanation of the existence of the points of weakness, the difference in expansion itself still remains to be explained. A study of the data reveals that

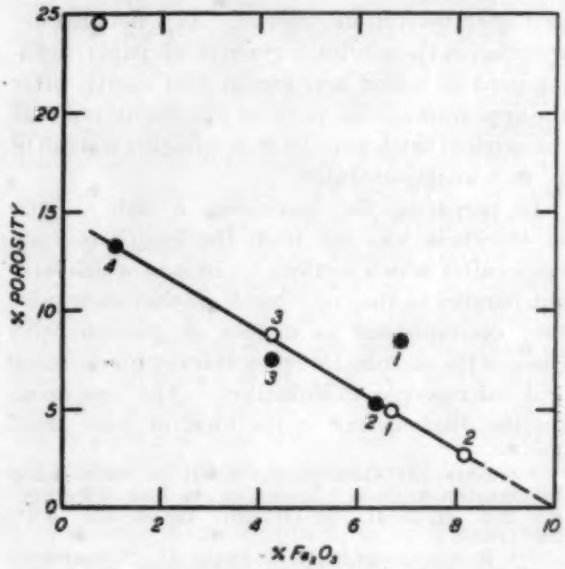

FIG. 2.—Curve showing correlation between porosity and Fe_2O_3 content; black disks, uninsulated brick; circles, insulated brick; numbers refer to zones.

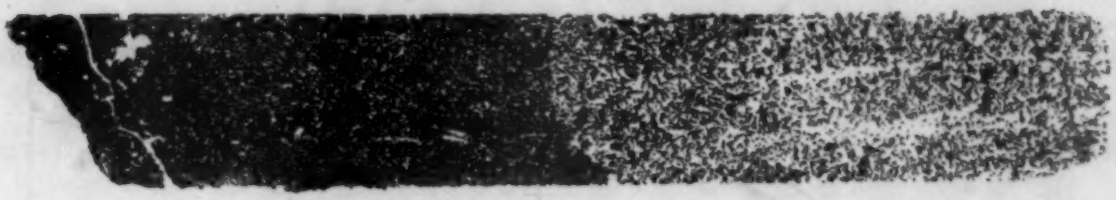

FIG. 3.—Ink print of semipolished surface of uninsulated brick, showing limit of penetration of iron oxide.

in each instance this difference arises almost entirely from a difference in the change of length at the cristobalite inversion (about 250°C) and is therefore to be associated with a difference in the distribution of cristobalite.

Comparing zones 4 and 5 of the uninsulated brick, zone 5, which probably represents fairly closely the structure of the brick as received from the manufacturer, contains a relatively large proportion of cristobalite and, in spite of the fact that the temperature of this zone in service lies within the stability range of tridymite (as will be demonstrated later), the rate of transformation is so slow that cristobalite persists. On the other hand, in zone 4, which represents the highest level to which iron oxide diffused, the silica has been largely converted to tridymite as indicated by the thin section prepared by Harvey as well as by the expansion curve; hence, at the cristobalite inversion the increase in length of zone 4 is much less than that of zone 5. The difference in expansion, and consequently the position of the zone of weakness, is therefore to be expected at the farthest level to which the fluxing iron oxide has penetrated, or in view of the relation between Fe_2O_3 and porosity, at the level of sudden decrease in porosity. Since the penetration of iron oxide appears to take place primarily through movement of the liquid phase, we should expect to find excess iron oxide only in that portion of the brick which was maintained above the eutectic temperature corresponding to the proportion of the several constituents actually present in the brick. According to Bowen, Schairer, and Posnjak,[6] the ternary eutectic temperature in the system FeO–CaO–SiO_2, which can be taken as a close approximation to the system we are dealing with in the used brick,[7] lies at 1105 ± 3°C (2020°F). Although the presence of traces of other oxides lowers this temperature slightly, we may, without serious error, take 1100°C (2010°F) as the lowest temperature at which liquid exists at equilibrium, and, on this basis, the surface which separates the dense glassy-appearing portion from the original porous material is located at that level in the brick at which the maximum temperature in service was 1100°C (2010°F). The position of this surface, easily seen in Fig. 3, coincides with that of the sudden change in the character of the expansion and the zone of weakness.

With respect to the difference between zones 1 and 2, the former, in which the silica is present chiefly as cristobalite, is that portion of the brick in which the average temperature must have ex-

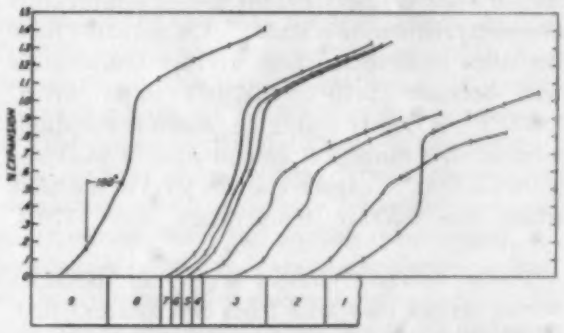

FIG. 4*a*.—Expansion of the several zones in the uninsulated brick; large divisions correspond to 100°C as indicated.

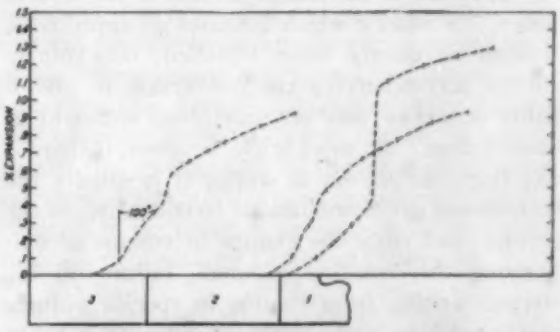

FIG. 4*b*.—Expansion of the several zones in the insulated brick; large divisions correspond to 100°C as indicated.

[6] N. L. Bowen, J. F. Schairer, and E. Posnjak, "The System CaO–FeO–SiO_2," *Amer. Jour. Sci.*, **26**, 193 (1933).

[7] Miller uses data on the system FeO–SiO_2 as a basis for his speculations, but the ternary system more nearly represents the true composition of this portion of the brick.

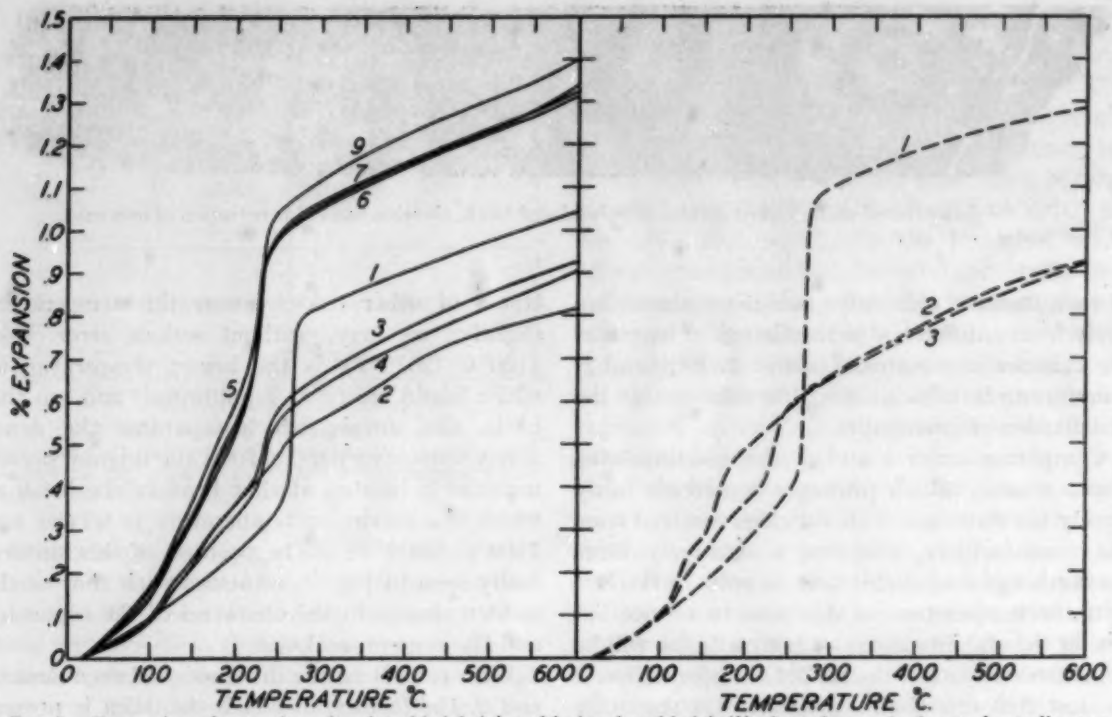

FIG. 5.—Expansion of zones in uninsulated brick (*a*) and in insulated brick (*b*) plotted on a single set of coördinates; numbers refer to zones.

ceeded 1470°C (2680°F), the lowest temperature at which cristobalite is stable. On the other hand the silica in zone 2, whose average temperature was between 1470°C (2680°F) and 870°C (1600°F), is largely tridymite, which is the stable form in that range. A second zone of weakness is therefore to be expected at the level in the brick where the average temperature was 1470°C (2680°F).

The destructive stresses set up in the brick during service may arise from two sources: first, the characteristic change in volume accompanying the reactions and transformations, such as the conversion of cristobalite to tridymite, and second, the difference in thermal expansion of the several zones. In a brick which contains an appreciable amount of quartz when installed, the volume change accompanying the conversion to cristobalite in service may set up stresses sufficient to cause failure. In most brick, however, if there is any large conversion in service it is usually the transformation of cristobalite to tridymite, or the reverse, and since the change in volume accompanying this reaction is small, failure due to stresses arising from change in specific volume seems unlikely, and the major difficulty is probably due to a difference in thermal expansion.

Figure 5 shows that above 300°C (570°F) the slope of the several curves, that is, the instantaneous expansion coefficient, is nearly the same, but below 300°C (570°F), particularly in the range 225 to 275°C (435 to 525°F), there are marked differences in the expansion of the zones. There is, therefore, relatively little danger of failure or serious spalling while a roof, either insulated or uninsulated, is hot. If, however, an uninsulated roof cools to such a temperature that the boundary marking the upper limit of penetration of iron oxide, that is, the boundary between zones 4 and 5 in the brick, is at a temperature near 250°C (480°F), there is a considerable chance for a failure. If the roof cools still further so that the temperature of the boundary between zones 1 and 2 falls to 250°C (480°F), spalling is again likely to occur. Obviously, the same danger is present on reheating through this range. Since zones 4 to 9 are not present in the insulated roof, the danger of failure is considerably reduced and spalling should be limited to zone 1.

Briefly summarizing these results, it is concluded that, for any roof brick which has been in service long enough to absorb iron oxide and to establish equilibrium with it, the danger of failure from differences in thermal expansion is small as

long as the roof is kept hot, but that when the roof is cooled there are two zones of weakness where spalling is likely to occur. The first is at that level where the average temperature had been 1470°C (2680°F), the second is at the level of farthest penetration of iron oxide. If, by insulating the roof, the temperature of the outside of the brick is raised above 1100°C, only one zone of weakness is present on cooling, which indicates

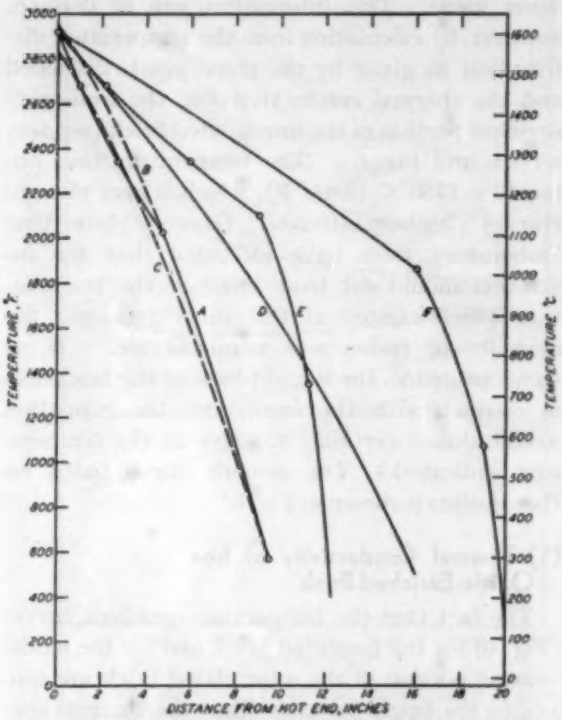

FIG. 6.—Estimated gradients in the brick under different conditions:
(*A*) Curve for 9-inch uninsulated brick.
(*B*) Harvey's estimate for a 9-inch brick, uninsulated, based on Larsen and Schroeder's measurements.[8]
(*C*) Harvey's modified curve for 9-inch uninsulated brick.
(*D*) Curve for original uninsulated brick (16 inches).
(*E*) Curve for 9-inch insulated brick and insulation.
(*F*) Curve for original insulated brick (16 inches) and insulation.

that insulation may have some advantages in addition to its primary function of saving heat. Whether failure does or does not occur depends upon the conditions prevailing in each individual case, but experience seems to show that failure at the boundary of zones 4 to 5 is more common than between zones 1 and 2.

(2) Distribution of Temperature in Brick while in Service

The conclusions just drawn involve indirectly the temperature gradient along the length of the brick, and as this gradient serves as a basis for calculations on heat flow through the roof and for a study of variations in the properties of cristobalite with temperature of formation, it becomes of interest to investigate it more thoroughly. Harvey[1] suggested a temperature distribution for the uninsulated brick based upon the direct measurements of Larsen and Schroeder.[8] The objection to Harvey's interpretation, which he also recognizes, is that Larsen and Schroeder made their observations on a new roof before an appreciable amount of iron oxide had been absorbed; hence, their curve, and consequently Harvey's, is smooth and continuous, whereas one would expect to see a discontinuity, or point of inflection, at the limit of iron-oxide diffusion, because the thermal conductivity of the zones in which the pores have been filled with the liquid phase should be greater than the conductivity of the rest of the brick. We have therefore reëxamined the evidence bearing on this gradient and have modified Harvey's curve accordingly.

We have assumed, as did Harvey, that the temperature of the boundary between zones 1 and 2 was that of the lower limit of the stable range for cristobalite, namely, 1470°C (2680°F). Taking account of the fact that the temperature at this boundary must have fluctuated appreciably during operation, this implies that under the conditions existing in the brick the rate of conversion of cristobalite to tridymite was approximately equal to that of the reverse transformation, an assumption which is entirely reasonable because any inherent difference in the rates should be largely removed by the catalytic action of the iron oxide. We have also shown in an earlier section that the temperature of the boundary between zones 4 and 5 must have been close to the temperature of the ternary eutectic in the system CaO–FeO–SiO_2, that is, 1100°C (2010°F). This point lies above Harvey's final curve, and, largely by accident we believe, falls on Harvey's curve based on the temperature limits used by Larsen and Schroeder (see Fig. 6). Assuming with Larsen and Schroeder and with Harvey that the temperature of the cool surface of the uninsulated roof was about 300°C (570°F), we have based the distribution of temperature through zones 5 to 9 on the gradients found by Larsen and Schroeder.

[8] B. M. Larsen and F. W. Schroeder, "Service Conditions of Refractories for Open-Hearth Steel Furnaces," *Carnegie Inst. Tech. Bull.*, No. 23, 122 pp. (1935).

Finally, we can estimate the effective temperature of the hot surface of the roof. Harvey's curve indicates a temperature of approximately 1545°C (2815°F), which we feel is rather low because the inner face in both brick shows unmistakable evidence of having been fluid at least some of the time. Greig[9] has shown that in the system CaO–FeO–SiO_2 the temperature at which the composition represented by zone 1 is completely molten is close to 1690°C (3075°F), a temperature which may, however, be somewhat reduced by the presence of other oxides. Undoubtedly the hot face of the roof had attained this temperature a number of times during its life in service, but it is believed that its prevailing temperature was somewhat lower than this. Larsen and Schroeder state that the average temperature of an open hearth is approximately 1590°C (2900°F) with sharp-working furnaces usually finishing their heats with a roof temperature between 1600°C (2910°F) and 1620°C (2950°F). As the former figure corresponds to what is considered normal operation in many steel plants in the district in which the brick were used, we have selected it as the best average value and have taken it as the effective surface temperature. Drawing a smooth curve through these three points, we find that it is convex to the length axis and that, as predicted, there is a change of curvature between zones 4 and 5. We believe that this curve, although based on indirect evidence, represents a fairly close approximation to the average condition of the brick while in service.

In the insulated, just as in the uninsulated, brick the boundary between zones 1 and 2 is taken as the level at which the temperature was 1470°C (2680°F). The hot face appears to have been closer to complete fusion than in the uninsulated brick so that its prevailing temperature must have been slightly higher, but we have assigned to it the approximate temperature of 1600°C (2910°F), which is sufficiently good for our purpose, because the temperature gradient for this brick is not steep in this region and the exact temperature is not of great importance. It is also reasonable to assume that the temperature of the boundary between zones 2 and 3 was the same in each brick, giving another point, which is, however, less certain than the other two because of the difficulty in locating the exact position of this boundary in the insulated brick. Finally, since the thin sections and iron analyses show that iron oxide diffused through the brick and into the insulation, the temperature of the cooler face must have been above the eutectic temperature, namely, 1100°C (2010°F), although how much above cannot be stated on the basis of this evidence alone. This information can be derived, however, by calculation from the temperature distribution as given by the three points discussed and the thermal conductivity of the iron-oxide enriched portion of the uninsulated brick (see next section and Fig. 8). The temperature thus obtained is 1150°C (2100°F), which is very close to Harvey's highest estimate. (Harvey states that "laboratory tests have indicated that the insulation should not have fused at the temperature which existed at this inner face, yet the evidence of fusion was unmistakable." If, as seems probable, the liquid phase of the brick was in contact with the insulation, the insulation would almost certainly dissolve at the temperature indicated.) The smooth curve based on these points is shown in Fig. 6.

(3) Thermal Conductivity of Iron Oxide-Enriched Brick

The fact that the temperature-gradient curves (Fig. 6) for the insulated brick and for the oxide-bearing portion of the uninsulated brick are convex to the origin indicates that the thermal conductivity of the altered brick *decreases* with increasing temperature, in contrast to the conductivity of the original brick which *increases* with temperature. This change in sign of the temperature coefficient, which results from the replacement of the poorly conducting gas in the pores with a better-conducting glass or liquid, is in agreement with calculations made by Eucken,[10] who, starting from experimental measurements on the conductivity of silica brick, computed the conductivity of pore-free silica brick containing different amounts of silica glass or liquid. His results (Fig. 7) indicate that when the glass or liquid content is small the temperature coefficient is negative. In the present case, the change in

[9] J. W. Greig, "Immiscibility in Silicate Melts," *Amer. Jour. Sci.*, **13** [73] 1–44 (p. 18) (1927); *Ceram. Abs.*, **6** [4] 157 (1927); "Liquid Immiscibility in System FeO–Fe_2O_3–Al_2O_3–SiO_2," *Amer. Jour. Sci.*, **14** [84] 473–84 (p. 483) (1927); *Ceram. Abs.*, **7** [2] 104 (1928).

[10] A. Eucken, "Heat Conductivity of Ceramic Refractory Materials; Calculations of Heat Conductivity from the Constituents," *Forschungheft*, No. 353 (Supp. to *Forsch. Gebiete Ingenieurw.*, **13** [3] (1932); *Ceram. Abs.*, **11** [11] 576 (1932); **12** [6] 231 (933).

porosity and to a lesser extent the structure, as revealed by an examination of thin sections, indicate that the amount of liquid present at temperature increased gradually from the boundary between zones 4 and 5 to the hot surface. We have estimated that this increase was from a small percentage in zone 4 to between 15 and 20% in zone

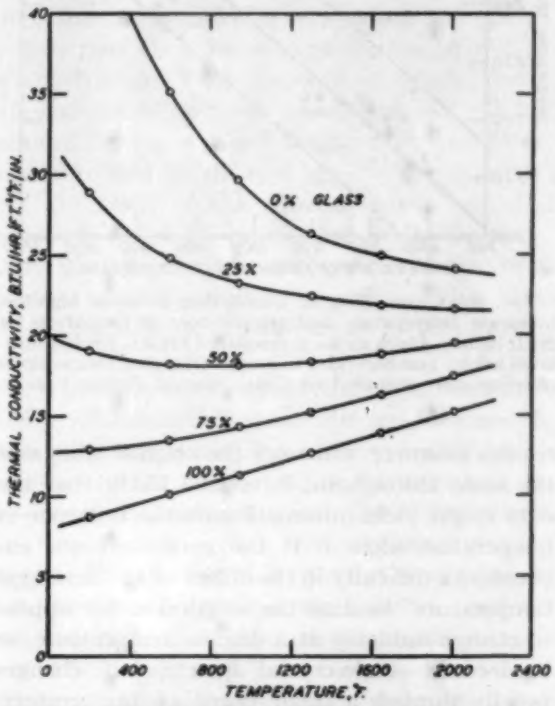

FIG. 7.—Curves showing thermal conductivity of pore-free silica brick containing different amounts of glass (or liquid) as estimated by Eucken.

1, the last figure being obtained by two independent methods: first, by estimation from the phase diagram of the system $CaO–FeO–SiO_2$ at that temperature, and second, from Harvey's microphotographs by the method of Rosiwal.[11] The liquid (or glass content) of this brick falls therefore between the two upper curves of Fig. 7, both of which have a negative slope. The curve, moreover, will not be parallel to those drawn, but, because of the increasing liquid content in the hotter zones, will have a greater negative slope, that is, there will be a greater decrease with in-

[11] S. F. Ravitz and H. A. Steane, "An Experimental and Theoretical Investigation of Quantitative Microscopic Mineralogical Analysis," Contribution 76, 1935; (unpublished data), abstracted in Yearbook Section, Mining and Metallurgy, p. 25 (Jan., 1936); Albert Johannsen, Manual of Petrographic Methods, p. 290 ff. McGraw-Hill Book Co., New York, 1918.

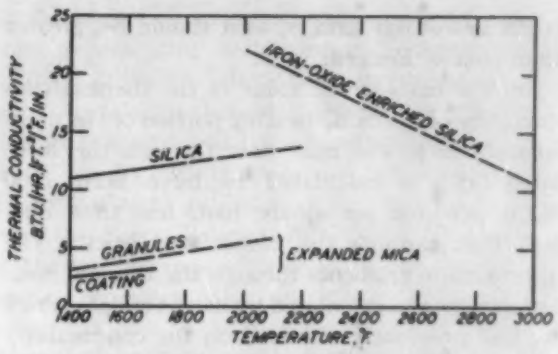

FIG. 8.—Comparison of calculated thermal conductivity of iron-oxide enriched brick (zones 1 to 4 of uninsulated brick) with that of the original silica brick and of the insulation.

creasing temperature than is indicated by Fig. 7.

Although an exact quantitative comparison with Eucken's data is hardly feasible, it is of interest to calculate the conductivity of the iron oxide-bearing zones to see how well it agrees with his deductions. The mean conductivity of silica brick is known fairly accurately in the temperature range corresponding to the temperature which prevailed in zones 5 to 9, and, using this information in conjunction with the temperature gradient taken from Fig. 6, the heat flow through this part of the uninsulated brick can be readily computed, the result being 3200 B.t.u. per hour per square foot. Making the reasonable assumption that the same amount of heat flowed through zones 1 to 4, the conductivity of these zones, based on the gradient of Fig. 6, is given in Fig. 8. This mean value should also hold with fair accuracy for the insulated brick. Values of the conductivity taken from this curve are compared

TABLE II

THERMAL CONDUCTIVITY OF IRON OXIDE-BEARING SILICA BRICK COMPARED WITH DATA OF EUCKEN

Mean temp. (°F)	Values of Pierce and Austin	Values of Bucken
	B.t.u./hr./ft.²/°F/in.	
2000	22	24
2500	17	22

in Table II with values obtained by extrapolation from Eucken's curve.[10] The agreement, although far from exact, is nevertheless remarkably good considering the simplifying assumptions made by Eucken in deriving his curves and the uncertainty in our estimation of the distribution of temperature near the cool face of the brick. Moreover, it is interesting to note that the temperature

coefficient of our data is, as it should be, greater than that of Eucken.

On the basis of the value of the thermal conductivity of the oxide-bearing portion of the uninsulated brick, the heat flow through the insulated brick is calculated to have been 1500 B.t.u. per hour per square foot, less than one-half that through the uninsulated brick. The approximate gradients through the thermal insulation were also calculated by means of data which we had previously obtained on the conductivity of the expanded mica granules and coating. The results show that the thickness of the layer of granules must have decreased almost $^3/_4$ inch by solution at the surface of the roof during operation, an estimate which seems entirely reasonable in view of the appearance of the fused layer on the brick and the penetration of glass from the top.

For comparison, the calculated heat flow through the original 16 inches of silica brick was 1820 B.t.u. per hour per square foot for the uninsulated roof and 950 B.t.u. per hour per square foot for the insulated roof, values which are 57% and 63%, respectively, of the flow through the roofs at the time the brick were removed. The gradients for the several cases are given in Fig. 6 and the heat flows are summarized in Table III.

TABLE III

COMPARISON OF HEAT FLOW THROUGH ROOFS OF TWO FURNACES AT BEGINNING AND END OF CAMPAIGNS

	Insulated (B.t.u./hr./ft.²)	Uninsulated (B.t.u./hr./ft.²)
Original	950	1820
At time brick were removed	1500	3200

(4) Variation of Properties of Cristobalite with Temperature of Formation

The expansion data, combined with the temperature distribution curve (Fig. 6) also yield information on some of the variations in the properties of cristobalite, particularly the variation in the high-low transition temperature. It has long been recognized that this temperature is influenced by two main factors, namely, the temperature at which the cristobalite formed, or at which it had been brought to equilibrium, and the kind of silica used as raw material. Experience has indicated that, in general, the higher the temperature of cristobalite formation the higher its inversion temperature on heating. In the present case it was observed that the inversion temperature of the cristobalite in the several zones into which iron oxide had diffused seemed to vary in a regular manner; and since the original silica was the same throughout, it seemed likely that the data might yield information on the influence of temperature alone. At the very start one encounters a difficulty in the choice of an "inversion temperature" because the length does not appear to change suddenly at a definite temperature, as it does in single-crystal quartz, but changes rapidly through a small range of temperature. Whether this is a property of cristobalite or whether it is characteristic of an aggregate of tiny crystals is not definitely known, but in view of the fact that aggregates of quartz crystallites do not show the sharp change observed in a single crystal, it is probably the latter. A certain amount of arbitrary selection is therefore necessary to determine the inversion temperature. We therefore have taken the temperature at which the inversion starts, determined by extrapolating the curves on either side if necessary. This procedure has the advantage that it removes to a large extent the uncertainty arising from the increase in temperature of the furnace during the finite time required for the apparent completion of the inversion.

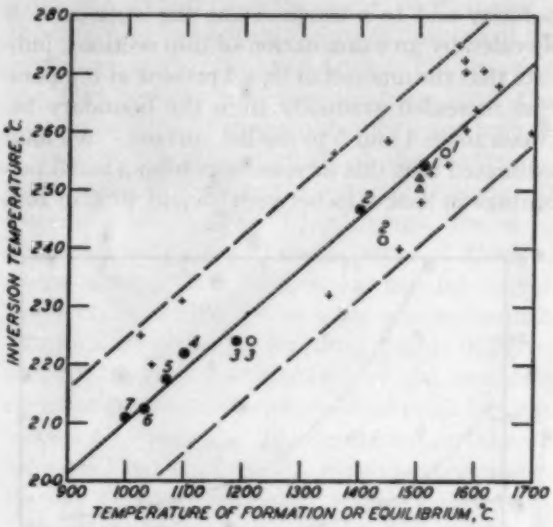

FIG. 9.—Curve showing correlation between high-low inversion temperature and temperature of formation for cristobalite; black disks, uninsulated brick; circles, insulated brick; numbers refer to zones; triangles, two samples of cristobalite prepared by Cole; crosses, data of Fenner.

The inversion temperatures thus obtained, plotted against the average temperature in service of the respective zones, fall on a straight line (Fig. 9) which may be represented by the equation, $t_i = 120 + 0.090\ t_f$, where t_i and t_f are the

temperature of the inversion and the temperature of formation (or equilibrium), respectively. In addition to the points for the roof brick, we have plotted data derived from expansion measurements on two cristobalite samples prepared under controlled conditions by S. S. Cole and a number of data reported by Fenner[12] are also included on samples made at different temperatures and using different raw materials. It is evident that these extra data (shown in Fig. 9 by the triangles and crosses, respectively) indicate the same general trend and can all be included within a band bounded by two lines parallel to that for the roof brick. This suggests that the slope of the equation given may be characteristic of all cristobalite, while the constant term depends on the nature of the raw material since the shifting of points within this band is probably due to differences in the original silica.

It is in some ways curious that there should be such a relationship, because the temperature of zones 2, 3, and 4 during service was within the range in which tridymite is the stable form and, in the presence of iron oxide, cristobalite should have been rapidly converted. Two explanations are suggested: (1) that the cristobalite separated from the liquid phase when the brick was cooled, which seems unlikely, because one would not expect to find so regular a behavior under these conditions; (2) that silica was always going into solution and crystallizing out again and that both forms tended to come out of solution, tridymite as a stable phase, cristobalite as a metastable phase; the relative amount of the two finally obtained, therefore, depended on the resultant of their relative rates of solution and crystallization at the temperature of the particular zone. This second explanation, which accounts for the observed variation, seems to be more likely than the first. It may be said, however, with some certainty, that since neither form dissolves iron oxide to a measurable extent, the variations are not due to differences in the composition of the liquid phase.

Another interesting correlation is obtained by plotting the change in length of each zone at the cristobalite inversion against the mean temperature of the zone in service (see Fig. 10), for the data fall on two straight lines intersecting at a point representing zero change in length and 1470°C (2680°F), the lowest temperature at which cristobalite is stable. Above this temperature, the expansion at the inversion appears to increase rapidly with temperature, but the data are hardly sufficient to establish this conclusion beyond question. Below 1470°C (2080°F), that is, in the stable range of tridymite, the change in length decreases with increasing temperature which, in view of the increase in rate of conversion of cristobalite with temperature, can be interpreted as indicating a decrease in the

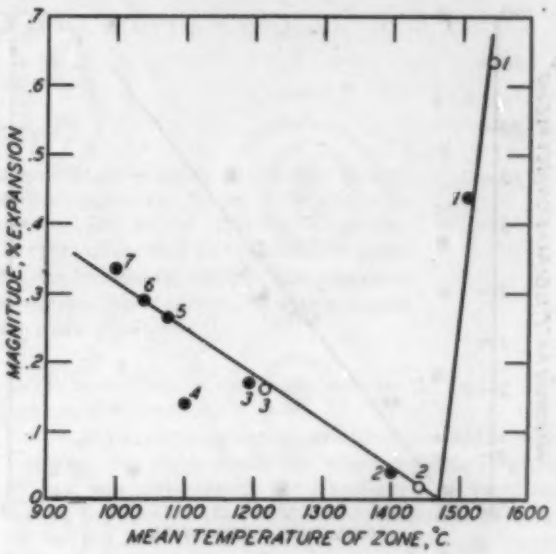

FIG. 10.—Curve showing relation between magnitude of the expansion at the high-low inversion and the temperature of formation for cristobalite; black disks, uninsulated brick; circles, insulated brick; numbers refer to zones.

amount of cristobalite. This means that it may be possible to determine the amount of cristobalite in a silica refractory from observations of the expansion in passing through the cristobalite inversion.

It should be noted that there is no indication in the expansion curves of the inversion of quartz at 573°C (1064°F), although quartz can be plainly seen under the microscope. This apparent suppression of the inversion in quartz has been observed before[13] and we believe that it is to be expected whenever quartz, originally present in large grains, has been partially converted to cristobalite. Travers and Goloubinoff[13] take a somewhat different view and hold that what ap-

[12] Taken from a table given by R. B. Sosman, The Properties of Silica, p. 130. McGraw-Hill Book Co., New York, 1927.

[13] See footnotes 3 and 4, p. 277.

pears to be quartz is actually an amorphous form of silica, but this explanation seems unreasonable to us considering the definitely crystalline character of the quartz in the thin sections.

We have also plotted the change in length at the cristobalite inversion against the maximum temperature-rate of expansion (that is, the steepness of the curve at the inversion) as determined directly from the rate of passage of the interference fringes at a fixed rate of heating. When plotted on logarithmic coördinates (Fig. 11), the data are best represented by a straight line, indicating that the maximum rate of expansion increases directly

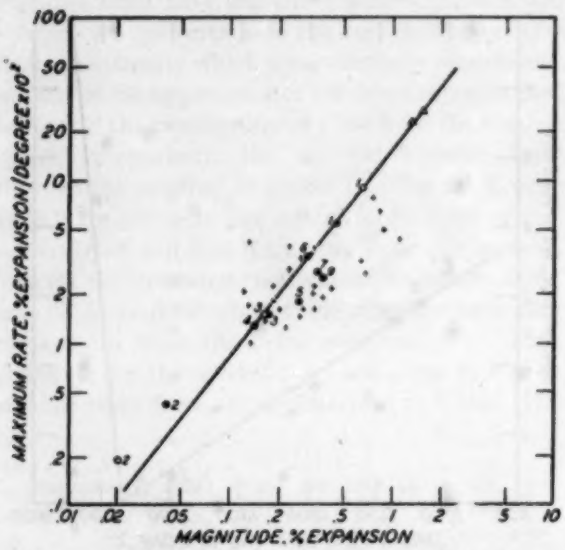

FIG. 11.—Curve showing relation between the steepness of the expansion curve of cristobalite at the high-low inversion and the total increase in length at the inversion; black disks, uninsulated brick; circles, insulated brick; numbers refer to zones; crosses refer to data for other samples of cristobalite.

with the change in length. In Fig. 11 we have also given data for a number of other siliceous materials for which we have measured the expansion at the cristobalite inversion (represented by crosses), and it is evident that they are roughly in agreement with the data obtained from the two brick. Since maximum rate of expansion is related to the magnitude of expansion, which in turn is related to the prevailing temperature of the zone (Fig. 10), one is tempted to correlate maximum rate of expansion and the temperature, which yields two curves of the same type as those shown in Fig. 10 and indicates that the maximum rate falls as the temperature approaches 1470°C (2680°F) and then increases sharply as the temperature rises above 1470°C (2680°F). Correlations of this last type, for which there is no logical background, while interesting and often instructive, must nevertheless not be relied upon too much without further, and preferably independent, checking.

In conclusion, we should like to emphasize that all our interpretations of the behavior of cristobalite depend on the correctness of the estimate of the temperature gradient and are, therefore, merely tentative. They should not be regarded as final until they have received an independent confirmation.

IV. Summary

(1) The linear thermal expansion of the several zones in used silica brick from an uninsulated and an insulated open-hearth roof has been determined over the range 20° to 600°C (68° to 1110°F).

(2) The results for the uninsulated brick show two abrupt changes in expansion between zones. The first, whose existence was predicted by Harvey, occurs at the limit of penetration of iron oxide, which is that level in the brick whose prevailing temperature in service had been 1100°C (2010°F), the eutectic temperature in the system CaO–FeO–SiO_2. The second change comes at the level at which the prevailing temperature in service had been 1470°C (2680°F), the lower limit of the stability range of cristobalite. Both changes are due to a discontinuity in the distribution of cristobalite in the brick.

(3) The temperature of the insulated brick was above 1100°C throughout so that only one change was observed.

(4) The position of the changes in expansion appears to coincide with that of the zones of weakness frequently observed in such brick. There is little danger of severe spalling or failure from thermal expansion as long as the whole roof is kept hot, but the danger increases as the roof is cooled and becomes greatest as the roof cools below 300°C (570°F).

(5) The temperature distribution through the brick while in service has been deduced from an examination of the composition and structure of the brick. Combining this gradient with data on the thermal conductivity of silica brick, it is possible to calculate the heat flow through the roof under various conditions, which information permits the calculation of the average conductivity

of the part of the brick containing excess iron oxide. The penetration of iron oxide raises the conductivity of the brick and causes the temperature coefficient of conductivity to become negative. The values for the thermal conductivity calculated in this manner are in agreement with those calculated by Eucken for a mixture of quartz and vitreous silica.

(6) It is shown that the inversion temperature of cristobalite increases with the temperature at which it is formed or at which it is brought to equilibrium.

(7) A relation is derived between the steepness of the expansion curve of cristobalite at its inversion and the expansion at this point. The steeper the curve, the greater is the total expansion.

Acknowledgment

The authors wish to acknowledge their indebtedness to F. A. Harvey for his coöperation in supplying the samples and in reading this manuscript and to R. B. Sosman for his advice and help throughout the investigation.

United States Steel Corporation
Research Laboratory, Lincoln Highway
Kearny, New Jersey

SPIT-OUT*

By C. J. Koenig

Abstract

A review is given of previous related investigations, and photomicrographs of various examples of spit-out in different life stages of development are shown. The effects on spit-out of the additions of substances such as carbon, sulfates, etc., to a normal earthenware glaze are described, as well as tests on the effect of vacuum and thickness of glaze.

While moisture sorption is an important factor influencing spit-out, it is suggested that the importance of its rôle is emphasized by the reaction of the resultant superheated steam with carbon, thereby producing increased gaseous pressure.

I. Introduction

(1) Literature Review

The dinnerware industry is indebted to Mellor[1] for his complete and interesting study of the problem of spitting of glazes in the decorating kiln. A review of his paper is presented as well as the work of other investigators.

Mellor lists the following main causes of spitting:

		Hypothesis	
Spitting	Body fault	(1) Unburned carbon in the body	
		(2) Adsorbed gases	(*a*) carbonaceous
			(*b*) moisture
	Glaze fault	Absorbed gases	(*a*) carbonaceous
			(*b*) moisture

Among the minor assumptions are the sulfate hypothesis and the bursting of bubbles in the glaze, the latter of which is discredited by the consideration that in the decorating kiln these bubbles are just as likely to be sucked inward as to burst outward.

The gas pressure developed during the burning of carbon in the body at a red heat in the decorating kiln is attributed to the local raising of the temperature by the heat of combustion of the carbon.

Cowan[2] found that glazes, in which sulfates had been introduced, spit under conditions where nonsulfated glazes did not spit and suggested that sulfates are formed not only in the glaze by the sulfur-dioxide present in the gases of the glost kiln, but that this gas is also taken up by the body.

Robson[3] found that kiln atmosphere is a vital factor causing spit-out and that the superheated steam from the products of combustion is the primary cause.

Bleininger[4] states that spitting-out in decorating is connected with rehydration as well as the accidental production of excessive temperatures. Different clays show different tendencies toward absorption.

II. Experimental Data and Discussion

(1) Source of Gas

The spit bubbles are readily observed in their various stages of development with the aid of the microscope.

The photomicrographs (Fig. 1) show a plate three months old, which was fired to 1500°F in an

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, March 31, 1936 (White Wares Division). Received May 8, 1936.

[1] J. W. Mellor, "Spitting of Glazes in the Enamel Kiln," *Trans. Ceram. Soc.* [Eng.], **35** [1] 1–42 (1936).

[2] R. G. Cowan, "Spitting-Out, a Phenomenon of the Decorating Kiln," *Trans. Amer. Ceram. Soc.*, **9**, 493 (1907).

[3] J. T. Robson, "Glaze Spit-Out," unpublished data.

[4] A. V. Bleininger, "Physical Factors in Pottery Manufacture," *Ceram. Age*, **12** [1] 4–6 (1928); *Ceram. Abs.*, **7** [11] 769 (1928).

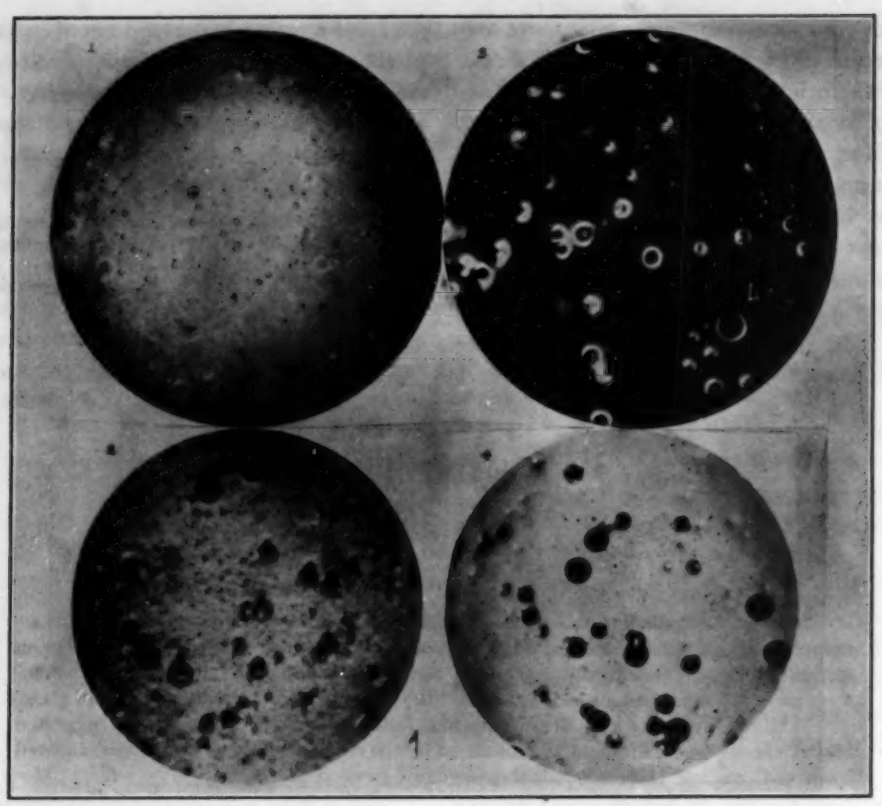

FIG. 1.—(1) Illumination: oblique partially crossed pola screen, 25×; (2) illumination: oblique plus specular, 25×; (3) illumination, oblique no pola screen, 25×; (4) illumination: specular, 25×.

electric kiln in $5^1/_2$ hours. The same plate when new did not spit-out even though fired to 1600°F in $5^1/_2$ hours.

In Fig. 2, the pictures are cross-sectional views of spit-out plates showing both glaze and body. Figure 2(*a*) illustrates a bubble just entering the glaze; Fig. 2(*b*) shows three "pre-natal" spits.

Figure 3 is a cross-sectional view of a typical spit-out. The relatively large size of this spit-out as compared to the thickness of the glaze makes it appear as if it were formed from gas originating in the body. The photomicrographs (Fig. 4) show thin sections of glazes which have spit-out.

(2) Glaze Pellets

A normal earthenware glaze was fused in a fireclay crucible and small $^1/_2$-inch cube pellets

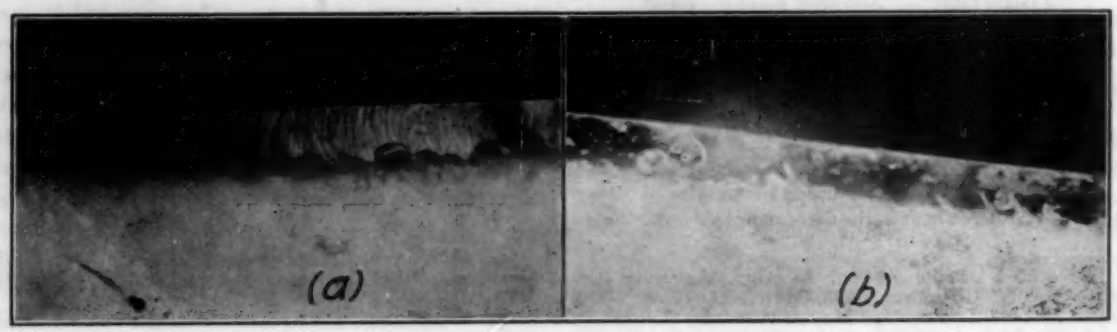

FIG. 2.—Cross-sectional views of spit-out, 65×.

FIG. 3.—Spit-out, 65×.

were tested for spit-out under the following conditions and with the results noted: (*a*) when first formed, 1500°F in 5½ hours, no spit-out; 1700°F in three hours, no spit-out; (*b*) after damp storage one month, no spit-out; bottle glass, damp storage one month, frosted surface (firing as above).

(3) Thickness of Glaze

New 5-inch bisque plates were dipped at the Crooksville China Company to secure thin, medium, and thick glaze and were glost fired as usual. None of this ware spit-out regardless of thickness. However, after four months' storage (room conditions) only the thin glazed ware did not spit when fired to 1400°F in 5½ hours. All thicknesses spit when fired to 1500°F in 5½ hours.

Numerous specimens of spit-out ware indicated that, in a given plate, spitting occurs most abundantly where the glaze is thickest. This is explained apparently by the fact that the thin glaze will have been relatively more hardened by the solvent action of the glaze on the body in the glost oven.

Along the same line of thought, numerous plants have reported that less spit-out occurs with hard biscuit fire than with soft biscuit fire, the latter taking a thicker glaze coating. Likewise, hard glost is reported to reduce spit-out, and this may be attributed to the fact that the higher fire will have increased the refractoriness of the glaze.

(4) Effect of Vacuum

Three pilot tests were made to determine the effect of high vacuum on spit-out,[5] using a vacuum electric furnace.

Test No. 1: The test specimen was a 1½-inch square piece broken from the center of a 7-inch plate about two years old. It was heated in the vacuum furnace to 1300°F in one hour and 20 minutes and subjected to a vacuum of 742 millimeters (barometer 747), which gave 5 millimeters' pressure for 5 minutes before reaching 1300°F (temperature increase was slight during this time). The furnace was raised from the quartz tube to observe the specimen without removing it. No spit-out could be seen.

The furnace was then lowered over the tube and specimen, and the temperature was raised to 1380°F in about 15 minutes, leaving the vacuum on (5 millimeters' pressure) for 20 minutes. The specimen was removed at once and observed to be very slightly spit-out.

Test No. 2: This test was made on a 1½-inch square specimen broken from the bottom of a new 5-inch plate (Crooksville). Under the microscope, with high magnification, small bubbles were observed scattered through the glaze. These could not be seen with the naked eye.

[5] G. A. Loomis performed the following tests on the effect of vacuum.

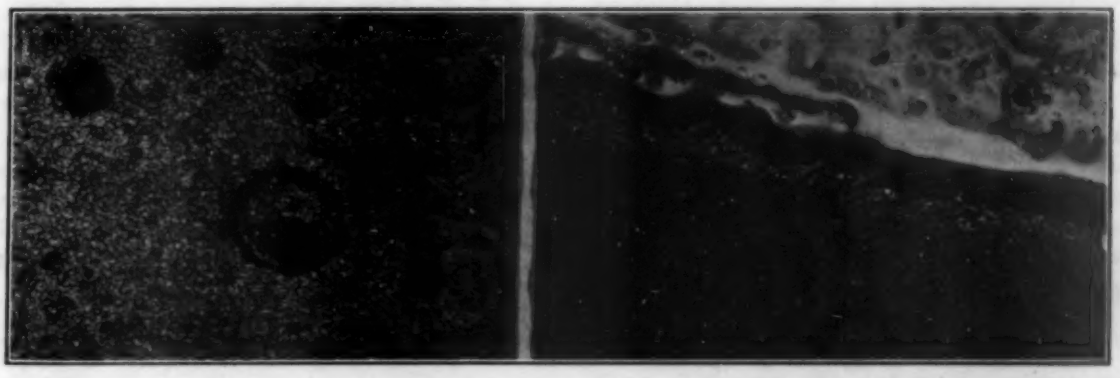

FIG. 4.—(1) Thin section of spit-out glaze parallel to surface; (2) thin section of spit-out glaze showing boundary line between body and glaze, (*a*) Canada balsam, (*b*) glaze, and (*c*) body; 65×.

TABLE I

ADDITION OF OXIDIZING AGENT ($KClO_4$) TO BODY AND GLAZE OF EARTHENWARE TYPE*

Glaze No.	Effect of Damp Storage			
	1	2	3	4
Additions dry weight (%) body	3		3	
Additions dry weight (%) glaze	2	2		
Appearance of glaze prior to testing	Normal texture slightly smoother	Normal texture slightly smoother	Normal texture	Normal texture
Fired to 1500°F in 5 hr.	No spit-out	No spit-out	No spit-out	No spit-out
Fired to 1600°F in $5^1/_2$ hr.	No spit-out			No spit-out
Fired to 1750°F in $4^1/_2$ hr.†	No spit-out	No spit-out	No spit-out	No spit-out
Fired to 2000°F in $3^1/_2$ hr.		No spit-out	No spit-out	
Fired to 1600°F in 5 hr. after damp storage 1 mo.	Spit-out	Spit-out	Spit-out	Spit-out
After one month storage (room conditions)	Very slight spit-out		Slight spit-out	
Fired to 1500°F 5 hr. after dry storage 1 mo.		No spit-out		Little or no spit-out
After damp storage 1 mo.	Spit-out		Slight spit-out	

* Paden City Pottery Co.
† Same plates as fired to 1500°F in 5 hr.

The furnace containing this specimen was heated to 1380°F in one hour and 10 minutes; the vacuum was then applied (6 millimeters pressure), and both vacuum and temperature were held for one hour and 20 minutes. The specimen was then removed. It was found to be only slightly spit-out, about the same as in the first test.

Test No. 3: The specimen used was another piece from the same plate as in test No. 2. It was heated to 1445°F in $1^1/_2$ hours. Then the vacuum was applied. The temperature (1445°F) and pressure (6 millimeters) were held for one hour.

This specimen showed little actual spit-out, but the glaze was full of bubbles large enough to be seen without magnification.

(5) Tests of Small Glazed Butters

Bisque specimens having 10% absorption were tested as well as some having about 6% absorption. None of these butters showed any signs of spitting even though fired to 1650°F in $5^1/_2$ hours after three years' storage.

The absence of stilt marks is undoubtedly a factor affecting spit-out in that less water is absorbed.

(6) Oxidation of Carbon in the Body

Carbon occurs in clays as vegetable matter, carbonaceous matter of asphaltic or bituminous character, and as anthracite carbon. For this reason, not only the amount but also the type of carbon must be considered. The favorable range for the removal of carbon in the biscuit kiln is between 500 and about 900°C. Since difficulty is encountered in oxidizing many ceramic bodies, owing to the lack of sufficient penetration of air into the ware, the addition of a small amount of a

TABLE II

EFFECT ON "SPIT-OUT" OF ADDITIONS OF VARIOUS SUBSTANCES TO GLAZES*

Glaze No.	0	1	2	3	4	5	6
Additions	None	5% bituminous carbon	5% anthracite carbon	2% calcium sulfate	5% sulfur	2% barium peroxide	3% barium nitrate
Appearance of glaze prior to testing	About the same as regular Crooksville texture	Texture fair	Texture fair	Satiny dull finish due to many small bubbles	Texture fair	Texture Fair	Texture good
Fired† to 1500°F in 5 hours	No spit-out	Slightly spit-out	Spit-out	Slightly spit-out	Slightly spit-out	No spit-out	No spit-out
Fired at Crooksville China Co.	No spit-out	No spit-out	No spit-out	Slightly spit-out	No spit-out	No spit-out	No spit-out
Fired† to 1500°F after damp storage 1 mo.	Pronounced spit-out	Pronounced spit-out	Pronounced spit-out	Pronounced spit-out	Pronounced spit-out	Pronounced spit-out	Pronounced spit-out

* Crooksville China Company glazes.
† Firing schedule 380°F/1 hr., 660°F/2 hr., 935°F/3 hr., 1220°F/4 hr., 1500°F/5 hr., 1500°F/6 hr.

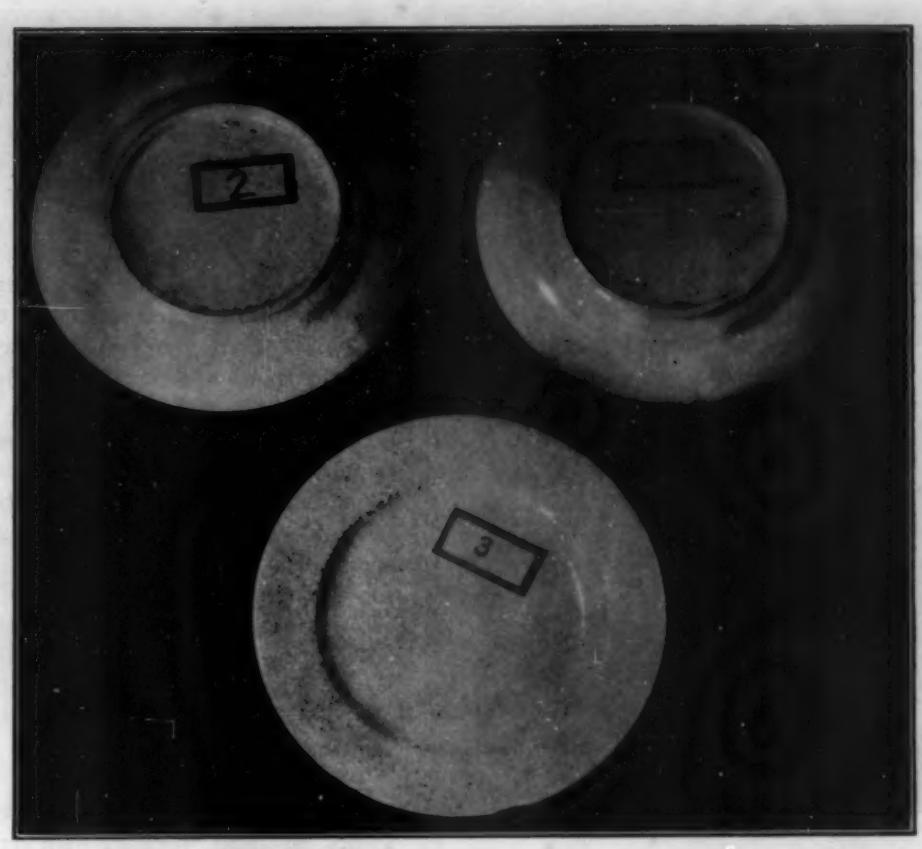

FIG. 5

powerful oxidizing agent would seem to be beneficial.

Potassium perchlorate was tried for this purpose, since it is relatively insoluble in water and is a very strong oxidizing agent.

While it decomposes at a little lower temperature than is desired (400°C), it was thought that the intimate contact of pure oxygen with carbon would favor the removal of the latter.

Table I contains data on results of the addition of $KClO_4$ to a body and glaze of earthenware type and also the effect of damp storage.[6]

Inasmuch as neither the treated nor the untreated plates could be made to spit-out when new, no conclusions could be drawn on this test. The important influence of moisture, however, is clearly shown.

Table II shows the effect of additions of various substances to the regular Crooksville glaze. These treated glazes were applied to 5-inch Crooksville bisques by spraying and fired to cone 3 down on a normal glost-firing schedule.

Figure 5 shows (1) a picture of a spit-out plate in which 5% anthracitic carbon had been added to the glaze and (2) a picture of a plate with untreated glaze. These plates were fired (side by side) to 1500°F in 5 hours in an electric furnace. Plate No. 3 is similar to No. 1 except that it was subjected to damp storage for 3 weeks.

Figure 6 shows a photomicrograph of (1) a regular glaze and (2) a glaze to which 2% calcium sulfate has been added.

Figure 7 pictures four views of a $2^1/_2$-year old vitreous china plate which was fired to 1500°F in 5 hours: (1) front view showing clusters of dark spits; (2) back view showing clusters of dark spits and spits around pin marks; (3) photomicrograph of clump of dark spits indicated by arrow on front view; and (4) a cross-sectional photomicrograph of the same spits.

Figure 8 illustrates the increased tendency for glazes to spit-out where they have been scratched.

[6] These plates were made and fired at the Paden City Pottery Co.

III. Effect on Glazes of Hydrocarbons in the Kiln Atmosphere

The reports from many plants that spit-out is more likely to occur on ware on its second or repeated trips through the decorating kiln apparently are in agreement with Mellor's suggestion that the glaze can absorb appreciable amounts of hydrocarbon gases above 450°C and, when subsequently heated in an oxidizing atmosphere, the gases may burn below the surface to cause minute spits.

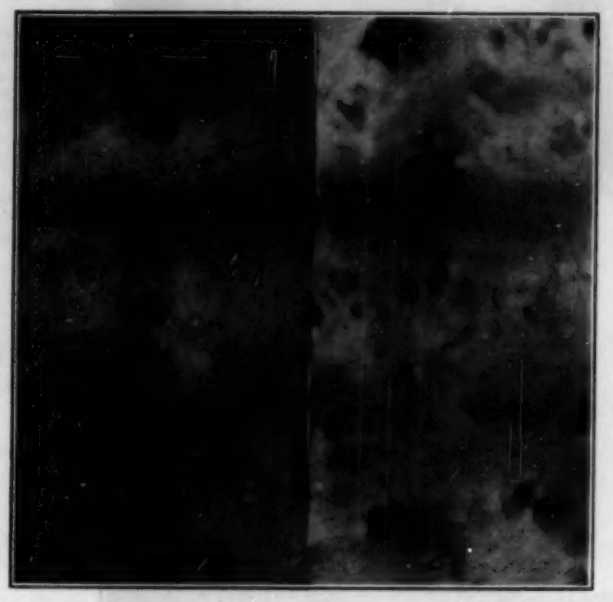

FIG. 6.—(1) Semiporcelain glaze; (2) semiporcelain glaze 2% $CaSO_4$; 65×

McDougal,[7] in tracing the cause for the appearance of numerous small craters in glazed tile, found a small crystal of silicon carbide at the bottom of each crater. He traced the occurrence of the silicon carbide to the inadvertent admixture of some silicon-carbide brick to the dry pan in which the refractories were crushed to produce a grog embodied in the tile mix.

Two plates made at the same time were placed in damp storage for two months; one of them was then dried at 350°F for one week. These plates were fired to 1500°F in 5 hours. Although both specimens spit-out, the one which was dried at 350°F spit-out decidedly less than the other.

A group of new plates did not spit-out when fired to 1500°F in 5 hours; however, after one year storage (room conditions) these plates spit-out when fired to 1400°F in 5 hours. One of the one-year old plates was dried at 350°F for two weeks and also at 775°F for ten hours before firing to 1500°F in an additional 3 hours. This plate did not spit-out.

[7] T. G. McDougal, A C Spark Plug Co., Flint, Michigan, personal communication.

IV. Summary

On the basis of facts of industrial experience and experimental data, the occurrence or absence of spit-out may be considered to be dependent upon the relative strength of two opposing forces. The aggressor is the gas pressure originating principally from the presence of moisture, carbonaceous material and, probably to a less extent, sulfates in the body and glaze. In opposition to this is the mechanical resistance of the glaze to ebullition of the gases. The greater the interval between the decorating temperature and the higher temperature at which appreciable softening of the glaze begins, the less likely is spit-out to occur.

While carbon of itself does not cause spit-out, its presence is a potential threat since, by reaction either with aerial oxygen or water-vapor, the gas pressure is increased and the importance of the rôle of moisture is thereby emphasized.

V. Appendix

(1) Theoretical Considerations

In an endeavor to explain the spitting of ware containing carbon the following consideration is suggested.

Since the hot carbon comes in contact not merely with the volume of oxygen and other air constituents which have penetrated into the ware both before and during the decorating fire, but also with water-vapor (the presence of the latter being pronounced in old ware), it is necessary to consider the combined effect of these two different gases, each of which may react to form various gaseous bodies.

The effect of oxygen upon hot carbon is expressed by the following equations:

				Molecular reaction heat (Cal.)	
C	+	O_2 →	CO_2	+97.65	
Volume negligibly small		1 volume	1 volume		(1)

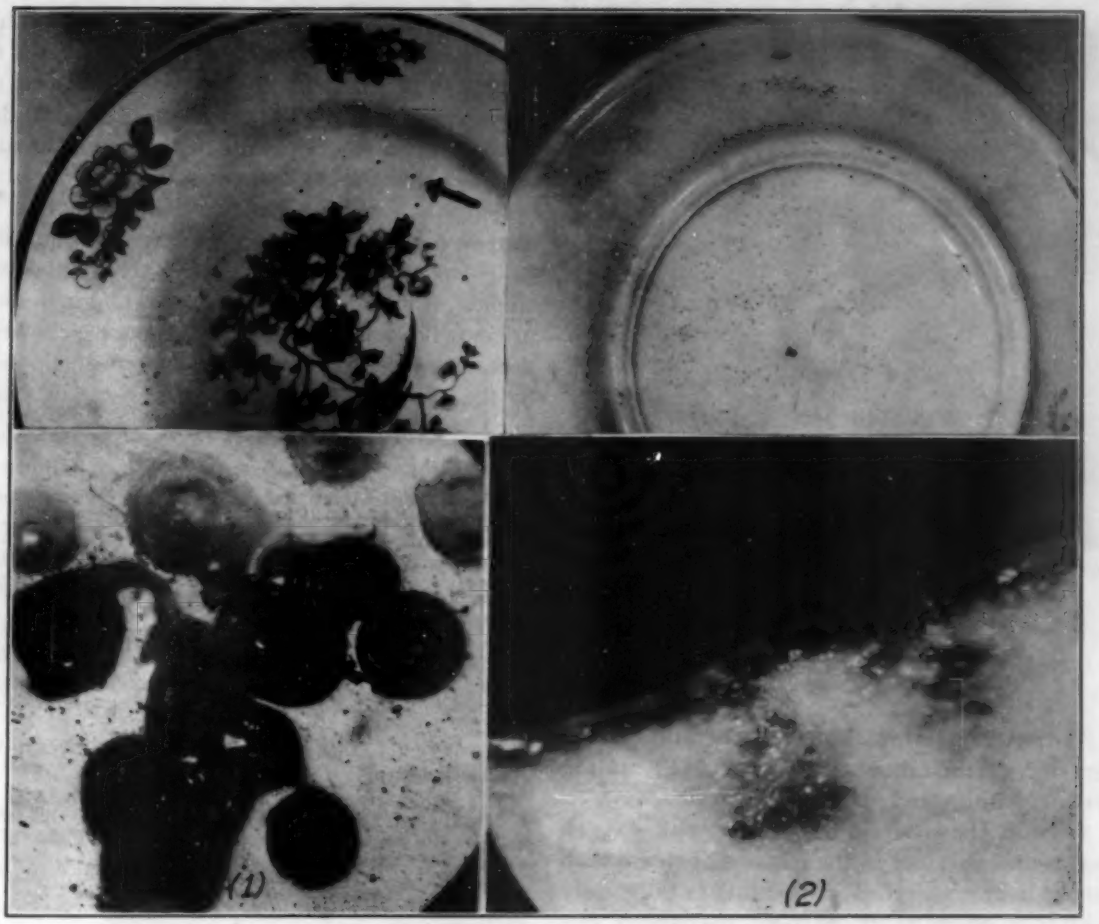

FIG. 7.—Spit-out on vitreous china: (1) and (2) represent top and cross-sectional views of dark clump of spits as indicated by arrow, 65×.

The development of gas pressure in the body as expressed by this equation is that due to the local elevation of temperature by the heat of reaction.

If carbon is in excess

				Molecular reaction heat (Cal.)	
C	+	CO_2 →	2 CO	−38.8	
Volume negligibly small		1 volume	2 volumes		(2)

An increase in pressure is produced in this case by the reaction. The volume percentage of the various gases of equation (2) which will be in equilibrium with solid carbon at 600, 700, and 800°C, respectively, is reported to be as follows[8]:

Temperature (°F)	Temperature (°C)	Gases (percentage by volume) CO_2	CO	N_2
1112	600	10.1	18.1	71.8
1290	700	3.1	29.4	67.5
1472	800	0.6	33.7	64.7

[8] Rambush, Modern Gas Producers, p. 10. Benn Brothers, Ltd., London (1923)

Thus, at 700°C (1290°F) the ratio of CO to CO_2 is about 10 to 1.

The reactions that take place between the incandescent carbon and water-vapor are determined largely by the temperature and relative masses of the reacting bodies. At 600°C (1112°F) carbon decomposes water-vapor appreciably in accordance with the equation:

						Molecular reaction heat (Cal.)	
C	+	$2H_2O$	⇌	CO_2	+ $2H_2$	+18.8	
Volume negligibly small		2 volumes (negligibly small as water)		1 vol.	2 vols.		(3)

Thus, according to this reaction, there is an increase of one volume of gas in addition to that produced by water when converted to vapor state. At a slightly higher temperature a small amount of carbon monoxide is formed conceivably according to the equation:

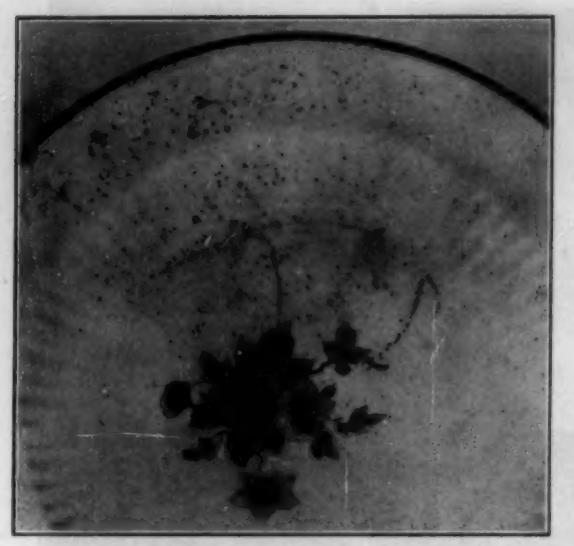

FIG. 8.—Spitting pronounced along scratches.

$$\underset{}{C} + \underset{}{H_2O} \rightarrow \underset{\text{1 volume}}{CO} + \underset{\text{1 volume}}{H_2} \quad \underset{\text{Molecular reaction heat (Cal.)}}{-28.8} \qquad (4)$$

At the temperatures, however, prevailing in the decorating kiln (about 1250 to 1400°F), we are primarily interested in the first reaction.

Since in the reaction of carbon with oxygen heat is liberated and in the reaction of steam with carbon heat is absorbed in amounts as previously expressed, these reactions tend to balance one another when they occur simultaneously. This feature is taken advantage of in certain types of water-gas production. If but small amounts of water-vapor are present, carbon spitting is dependent upon reaction with oxygen from the air, in which case the gas pressure receives an impetus both from heat liberated and the formation of increased gaseous volume according to equation (2). In ware which has been stored in damp climate, equation (3) predominates, and increased pressure is obtained, owing to reaction. The heat necessary for this reaction is, of course, supplied by the relatively enormous source of the decorating kiln fire.

Additional References

(1) Bernard Moore and J. W. Mellor, "The Adsorption and Dissolution of Gases by Silicates, 'Spit-Out,'" *Trans. Ceram. Soc.* [Eng.], 7, 1–20 (1907–1908); Discussion on 'Spit-Out,'" *ibid.*, 9, 1–16 (1909–1910); "The Adsorption and Dissolution of Gases by Silicates, 'Spit-Out,'" *ibid.*, 21, 289–316 (1921–22).

(2) Ohio Ceramic Industries Assn., Symposium on "Spit-Out," *Ceram. Ind.*, 25 [2] 88 (1935); *Ceram. Abs.*, 14 [10] 251 (1935).

(3) J. Miles, "Spit-Out of Glazes on Passing through an Enamel Kiln," *Trans. Ceram. Soc.* [Eng.], 21, 208–26 (1922).

Acknowledgment

The author wishes to record his indebtedness to G. A. Bole and G. A. Loomis for their contributions to this study and to the Crooksville China Company and Paden City Pottery for their coöperation.

ENGINEERING EXPERIMENT STATION
OHIO STATE UNIVERSITY
COLUMBUS, OHIO

USE OF SYENITE IN SEMIVITREOUS WARE, I*

(a) Physical Properties of Bisques and (b) a Glaze Containing Syenite

By C. J. Koenig

Abstract

Results are given on the physical properties of eight bodies, comprising that of a typical semiporcelain and seven bodies incorporating different nepheline syenites, both singly and in combination with feldspar, respectively. The relative viscosities of four nepheline syenites, a typical potash feldspar, and a soda feldspar are compared at five different temperatures. This study is to be followed by comprehensive plant tests.

I. Experimental

Eight bodies were prepared based on a typical semiporcelain; seven of these incorporated different nepheline syenites, singly and in combination with feldspar, respectively.[1]

The raw materials employed, with the exception of the vitrification agents, were those used in the regular body of the Crooksville China Company. The chemical analyses and grain-size classifications of the nepheline syenites and feldspars are given in Table I.

Table I

Chemical Composition of Vitrification Agents Used

Designation	Feldspars		Nepheline Syenites*			
	Potash A (%)	Soda B (%)	C (%)	D (%)	E (%)	F (%)
SiO_2	67.68	68.90	52.44	51.17	58.24	59.30
Al_2O_3	18.87	18.50	28.65	30.40	24.53	24.70
Fe_2O_3	0.054	0.10	0.09	0.15	0.069	0.05
TiO_2					Trace	0.01
CaO	0.49	2.20	1.24	0.61	1.00	0.27
MgO	None	Nil	0.10	0.23	0.07	0.02
Na_2O	2.78	7.20	12.87	12.96	10.74	9.91
K_2O	10.74	2.40	4.01	3.34	3.87	5.10
Ignition loss	0.17	0.40	0.68	1.15	1.28	0.44
Total	100.784	99.70	100.08	100.01	99.799	99.80
Residue on 100-mesh	0.05		0.03			
Residue on 200-mesh	0.85	0.50	0.66	0	0.88	0.7
Residue on 270-mesh	2.30		2.00		3.95	3.20

* Deposits located in Ontario, Canada.

Figure 1 is a pictorial representation of the relative viscosities of the fluxing materials at five different temperatures. For a given firing, the respective flux test pieces were placed in the same sagger in order to insure relative values.

The firing schedules to cones 5 and 6 were as follows: 4 hours to 810°F, 8 hours to 1050°F, 14 hours to 1750°F, and 50°F per hour to the respective end-points, which temperatures were held for one hour before shutting off the gas and plugging the air vents. The firing schedules to cones 8, 10, and 13 were approximately 8 hours to 850°F, 16 hours to 1400°F, 24 hours to 1800°F, and 40 to 50°F per hour to their respective end-points. The firing was then finished as in the previous case.

An interesting comparison of these materials is their relative abilities to wet the porcelain surface of the test blocks. The feldspars apparently have a higher force of cohesion than the syenites and break away clean from the porcelain surface, allowing the contracted feldspar to drop down in the slot before it becomes sufficiently active to attack the porcelain surface appreciably. On the other hand, the adhesion of the syenites is evidenced by the threadlike structure binding them to the porcelain surfaces.

All the syenites showed equal or greater fusion at cone 5 than the potash feldspar did at cone 8, while syenites Nos. C and D at cone 5 were apparently at a state nearly equivalent to that of the potash feldspar at cone 10.

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, April 1, 1936 (White Wares Division). Received May 8, 1936.

[1] For a preliminary progress report see C. J. Koenig, "Use of Syenite in Ceramic Bodies," *Ceram. Ind.*, **25** [6] 338 (Dec., 1935) and *Ceram. Age*, **27** [1] 262 (1936).

II. Body Compositions

Bodies are based on the composition used by the Crooksville China Company, substituting the following respective vitrification agents for their regular feldspar:

Body No.	
1	North Carolina feldspar*
2	Syenite F*
3	Syenite E*
4	Syenite C*
5	1/2 feldspar A, 1/2 syenite F*
6	1/2 feldspar A, 1/2 syenite C*
7	Flux content reduced 25%; other members proportionately increased; syenite F*
8	As No. 7 except syenite C is used

* See Table I.

III. Preparation of Bodies

Fifteen pounds dry weight of each body were prepared. The required weight of ball clay for the body was weighed out after crushing the lumps

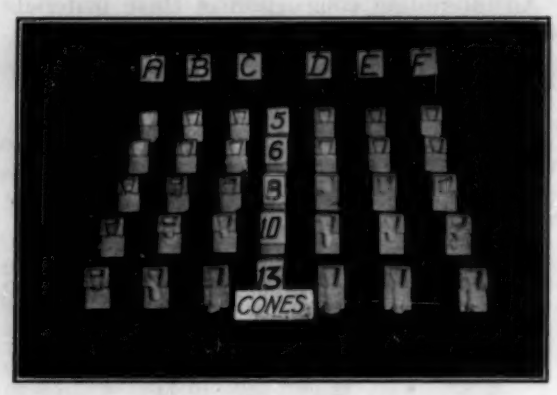

FIG. 1.

to 1/2-inch size. The materials were blunged with warm water for about 2 1/2 hours in a propeller-type blunger at a specific gravity of about 1.30, then passed through a 120-mesh screen and a magnetic separator. At this point a sufficient portion was removed for casting sag-test pieces; the remainder was dried to the desired consistency in plaster molds and then thoroughly wedged by hand.

IV. Testing

In general, the methods, apparatus, and calculations given by the American Ceramic Society[2] were used in determining water of plasticity, shrinkage, modulus of rupture, and elasticity.

Sag tests were made by firing the 3/8- by 1- by 7-inch cast specimens horizontally on supports five inches apart. The sag index of the body under fire is represented by the ratio of deflection to the span (five inches) multiplied by 100.

The coefficients of thermal expansion were calculated from linear thermal expansion determinations made upon fired bars, using a fused-quartz expansion apparatus designed by the National Bureau of Standards.[3]

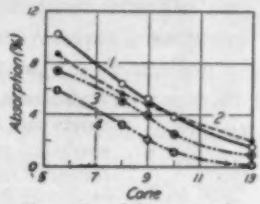

FIG. 2.—Absorption curves (direct substitution of syenites for feldspars).

V. Results

Values for modulus of rupture, Young's modulus of elasticity, and shrinkage are averages for ten test pieces from the cone 8 fire and five each from the cone 9 fire. Values for water of plasticity, sag test, and coefficient of linear thermal expansion are based on two determinations.

VI. Discussion

The syenites produced lower absorption than the feldspar when direct substitutions were made. Three parts of syenite C produced lower absorption than four parts of the potash feldspar.

FIG. 3.—Absorption curves (syenite content 3/4 normal feldspar content).

Absorption values on test bars ranged from 1.2 to 1.5% higher when fired to cone 9 on the regular biscuit 76-hour schedule at the Crooksville China Company than when fired to cone 9 at the Engineering Experiment Station, as previously described. This is in agreement with Watts' results.[4]

The vitrification ranges of the syenite bodies compared favorably with that given by potash feldspar. It is possible that this property is related to the apparently increased ability of the syenites to wet the particles with which they come in contact, thus taking more material into the

[2] Standards Report, *Jour. Amer. Ceram. Soc.*, 11 [6] (1928).

[3] Peter Hidnert and W. T. Sweeney, "Thermal Expansion of Magnesium and Some of Its Alloys," *Bur. Stand. Jour. Research*, 1 [5] 771–94 (1928).

[4] A. S. Watts, "Data on Influence of Firing Time on Properties of Some Whiteware Bodies," *Jour. Amer. Ceram. Soc.*, 19 [6] 175–76 (1936).

TABLE II

PHYSICAL PROPERTIES OF BODIES

Composition (Body No.)		1	2	3	4	5	6	7	8
Water of plasticity (%)		21	23	22	22	22	22	23	23
Linear shrinkage during firing (%)	Cone 8	4.7	4.3	5.1	5.8	4.9	4.9	3.7	5.0
	Cone 9	5.2	4.9	5.4	6.4	5.3	5.6	4.2	5.4
Total linear shrinkage (%)	Cone 8	9.3	9.6	10.2	11.0	9.8	10.2	9.0	9.8
	Cone 9	9.9	10.2	10.6	11.5	10.1	10.8	9.3	10.6
Modulus of rupture 5-in. span (lb./sq. in.)	Cone 8	5040	5000	5440	5930	5600	5110	5060	5950
	Cone 9	5360	5940	6550	6380	6940	5490	6230	6000
Modulus of elasticity (million lb./sq. in.)	Cone 8	4.35	4.54	5.80	6.07	4.85	4.80	3.82	5.05
	Cone 9	5.50	6.34	5.90	6.66	5.76	5.30	4.51	4.95
Sag index	Cone 7[3]	2.00	1.80	1.70	2.40	2.10	1.60	0.40	2.00
	Cone 9	2.60	2.25	2.60	2.90	2.40	2.40	1.10	2.25

glassy phase and thereby maintaining a higher viscosity in the liquid phase.

There are indications that a eutectic is formed between potash feldspar and syenite F since, when these materials are employed in a 50 to 50 proportion (body No. 5), the absorption is lower and the fired shrinkage and modulus of rupture are increased.

For the same degree of absorption, fired shrinkage was slightly lower with syenite F than with feldspar.

Bodies in which equal parts of syenites were substituted for feldspar, that is, Nos. 2, 3, and 4, gave higher values for modulus of rupture and modulus of elasticity, but for the same absorption modulus of rupture values fell within the same range.

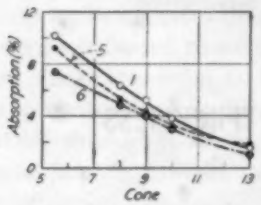

FIG. 4.—Absorption (combinations of syenite and feldspar compared with normal body).

For the same degree of absorption, the syenite bodies showed less tendency to warp than did the feldspar bodies.

The coefficient of linear expansion of the syenite bodies is greater than that of the feldspar body, and bodies combining feldspar and syenite are intermediate in this respect.

VII. Use of Syenite in Glazes

Two dozen four-inch plates, having the glaze composition given in Table III, were prepared at the Crooksville China Company, indicating promising results. The fired glaze batch contains 11.5% syenite F. These plates passed the auto-

TABLE III

GLAZE EMBODYING SYENITE F

Formula

0.43 CaO
0.26 PbO
0.12 K_2O
0.06 Na_2O
0.13 ZnO

} 0.27 Al_2O_3 0.31 B_2O_3 { 2.60 SiO_2

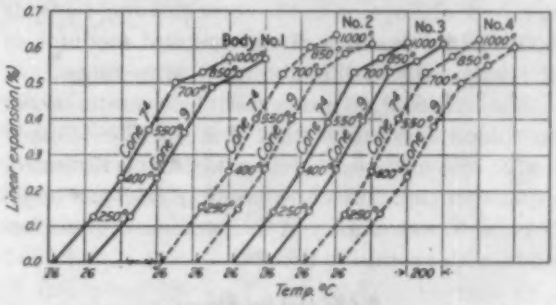

FIG. 5.—Percentage linear expansion curves for body specimens indicated.

Frit No. 1 (Highly acid-resistant lead frit)

0.26 PbO
0.0313 CaO
0.0219 K_2O

} 0.0627 Al_2O_3 { 0.5482 SiO_2

Combining weight 101.15

Raw materials: red lead, whiting, flint, potassium nitrate, and aluminum hydrate.

Frit No. 2

0.2496 CaO
0.0802 K_2O
0.0577 Na_2O

} 0.0775 Al_2O_3 0.31 B_2O_3 { 0.7363 SiO_2

Combining weight 98.836

Raw materials: syenite F, whiting, boric acid, flint, and potassium nitrate.

Mill addition

0.13 ZnO
0.1491 $CaCO_3$
0.0202 potash feldspar
0.1096 clay
0.9751 flint

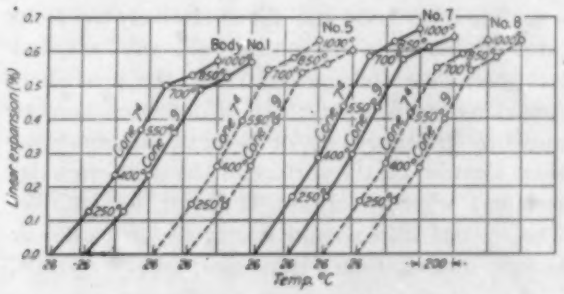

FIG. 6.—Percentage linear expansion curves for body specimens indicated.

clave, heat-shock, impact, and chipping tests satisfactorily.

VIII. Summary

The syenites studied fused on an average of three cones lower than the potash feldspar and exhibited more active wetting properties. Direct substitution of syenite for feldspar produced increased vitrification.

In cases where comparisons were possible, warpage was markedly less and firing shrinkage slightly less for syenite bodies having the same degree of absorption as the corresponding feldspar body, while modulus of rupture and modulus of elasticity values fell in about the same range.

The vitrification ranges of the syenite bodies compared favorably with that of the feldspar body. Syenite bodies had a higher coefficient of expansion than the corresponding feldspar body. Syenite F was employed in a standard glaze formula with promising results.

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(1) L. Ominin, "Replacing Feldspar by Nepheline Syenite in Mixes for Insulators," *Keram. i. Steklo*, **10** [6] 31–33 (1934); *Ceram. Abs.*, **13** [11] 296 (1934).

(2) A. D. Bogoslovskiĭ and L. G. Reznikov, "Low-Tension Porcelain Insulators with Wooden Sockets," *Ceramics and Glass*, **8** [1] 38–41 (1932); *Ceram. Abs.*, **11** [7] 422 (1932).

(3) A. I. Zhilin, "Use of Nepheline for Enamels," *Ceramics and Glass*, **6** [10] 485–88 (1930); *Ceram. Abs.*, **10** [4] 254 (1931).

(4) L. E. Krushel, "Experimental Melting of Glass from Marcupol's Nepheline Syenite at the Glass Works of Merepha," *Ukrainsky Silikaty*, No. 10, pp. 285–90 (1931); *Ceram. Abs.*, **12** [1] 12 (1933).

(5) I. I. Kitaigorodsky and S. W. Rodin, "Use of Rocks in Glassmaking," *Glass*, **8** [1] 8–12 (1931); *Ceram. Abs.*, **11** [6] 355 (1932).

(6) F. W. Preston, "Making Glass from Nepheline," *Glass Ind.*, **11** [6] 131 (1930); *Ceram. Abs.*, **9** [8] 627 (1930).

(7) G. Ya. Levenfish, "Manufacture of Glass-Containing Nepheline," *Ceramics and Glass*, **7** [1] 1–2 (1931); *Ceram. Abs.*, **10** [11] 762 (1931).

(8) I. L. Sills, "Minerals and Mineral Products Used in the Glass Industry," *Can. Mining Met. Bull.*, No. 267, pp. 365–87 (1934); *Ceram. Abs.*, **13** [9] 234 (1934).

(9) A. N. Dauvalter, "Slag Nepheline Glass," *Keram. i Steklo*, **9** [3] 26–27 (1933); *Ceram. Abs.*, **12** [9] 325 (1933).

(10) S. N. Solovianov, "Using Nepheline in Glass Manufacture," *Chim. & Ind.*, **26** [3] 631 (1931); *Ceram. Abs.*, **11** [1] 15 (1932).

(11) Samsonow, "Use of Nepheline in the 'Proletary' Glassworks," *Ceramics and Glass*, **7** [3] 3 (1931); *Ceram. Abs.*, **10** [10] 688 (1931).

(12) V. V. Vargin and N. K. Matveev, "Defects of Nepheline Glass," *Ceramics and Glass*, **7** [3] 5 (1931); *Ceram. Abs.*, **10** [10] 687 (1931).

(13) V. Vargin, "Application of Nepheline-Syenite of the Murman Coast in Glass Industry," U. S. S. R., Sci.-Tech. Dept. of Supreme Council of Nat. Econ., *Trans. Research Inst.* [Moscow], No. 15, 58 pp. (1929); *Ceram. Abs.*, **8** [8] 565 (1929).

Acknowledgments

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Engineering Experiment Station
Ohio State University
Columbus, Ohio

MEASUREMENT AND SIGNIFICANCE OF ENAMEL THICKNESS*

By H. H. Holscher

Abstract

Using the electric thickness gage, a study of broken enamel parts from the assembly floor and field has shown that it is more economical to take an immediate scrap loss on all parts which have an enamel thickness of 27 mils or more than to use the parts and pay the subsequent replacement costs. A brief discussion of the gage and its uses in the enamel shop are also given.

I. Introduction

The quality of porcelain enamel is generally defined from the standpoint of appearance; that is, if a surface looks good and if it is relatively free from pinholes, black specks, orange peel, waviness, and has good gloss and uniform color, the product is considered satisfactory. It is not necessary to measure imperfections or defects, inasmuch as their location on the surface of the part often determines whether or not the part is passable. The enamel also should not craze, fishscale, or become dull or stained in service; in other words, appearance and permanence of appearance are the main quality items of consideration.

Recently,[1] however, the item of serviceability has been studied with particular attention to breakage or chippage. It has been necessary to arrive at some means of evaluation of the chipping tendency of a certain piece, whether in the factory, during transportation, or any time during the use of the product. This has added, therefore, the subject of thickness as a criterion of quality. Since there are no known patching procedures or

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, April 1, 1936 (Enamel Division).

[1] H. H. Holscher, "Relation between Chipping and Thickness of Porcelain Enamel Coatings," *Ceram. Ind.*, **24** [6] 348–49 (1935); *Ceram. Abs.*, **14** [8] 183 (1935).

materials which are as durable as the porcelain enamel itself, it has generally been necessary to replace a chipped part in service at considerable expense.

The question of enamel chipping has been studied from several distinct viewpoints[2] as follows: (1) application of enamel, embodying all forms of process control; (2) product design, such as metal thickness, shape of parts, tolerances, types of assembly, brushing allowed, and inspection standards; (3) handling of product, such as assembly, storage, crating, transportation; and (4) faulty manufacture, including such items as improper dimensions, mislocated holes, and flanges off angle (these items are usually so nearly correct that they are not discovered until they have been the cause of losses).

Under process control, the greatest advantage to be secured is the control of enamel thickness by keeping the coating as thin as possible. In the final analysis, if any defect occurs in processing, the affected parts are reworked, thus contributing to thick coatings.

This idea is not new; innumerable references in the literature show that it has long been recognized. Shaw[3] states that thinness is the foremost item contributing to enamel toughness. Hansen[4] and Türk[5] also point to the danger of respraying as contributing to chipping. A recent "chip-proof" product is a very thin enamel on a thick metal base.[6] Ebright makes the following statement[7]:

> Certain definite standards of the number of coats should be decided upon and if the inspection department decides to throw out a piece, it should immediately be scrapped. It is only in this way that losses due to chipping from excessive coats of enamel will be eliminated.

A more recent case is that given by Aydelott and Pfeiffer[8] as follows:

> The establishment of the color-matching system with its rejections of parts with heavy enamel was reflected immediately in losses due to chipping. The reduction of losses in cabinet assembly were estimated to be 75 to 90%. A reduction of trouble in the customer's home was noted by the reduction in complaints of the sales and service departments.
>
> Contrary to what might have been expected, the scrapping of parts by color rejection did not increase the enamel shop scrap except temporarily and, in the end, actually caused its reduction. It was soon recognized that when a part had been reoperated more than twice it would not pass the color test. Consequently, it became standard practice to scrap all parts that were not satisfactory after two reoperations.

As pointed out above, the production of parts with thin enamel is only one of a group of items which should be given consideration in any study of breakage. Chipping may often be caused by design,[9] warping, careless handling, improper or insufficient use of brushing, as well as innumerable other items. It has been shown[6] that the enamel will fail when the metal is stressed beyond its elastic limit.

II. Measurement of Thickness

The original procedure in measuring thickness was to break the enamel and measure the broken section by means of a micrometer. This procedure was necessarily destructive to the part and could only be used where the part was already damaged or in a laboratory investigation where the enamel could be chipped from the steel after all other data were secured. Data reported in Figs. 1, 2, and 3 were obtained in this fashion. Generally, about one mil of enamel adheres to the steel (1 mil = 0.001 inch).

The second procedure was an attempt to eliminate this destructive feature so that ware could be measured without injury and consisted in measuring the overall thickness of the part by the micrometer. It was, therefore, necessary to know the thickness of the steel and of the enamel on the back side in order to calculate accurately the front-side enamel thickness. The original data on chippage[1] were taken by this procedure in which it was necessary to assume that the steel has nominal thickness. These results, however, may

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[2] These items are not necessarily listed in the order of their importance.

[3] J. B. Shaw, "Enamels for Sheet Iron and Steel," *Bur. Stand. Tech. Paper*, No. 165, p. 74 (1920); abstracted in *Jour. Amer. Ceram. Soc.*, **3** [9] 771 (1920).

[4] J. E. Hansen, Advanced Technique of Porcelain Enameling, p. 201. Enamelist Publishing Co., 1932; *Ceram. Abs.*, **11** [6] 350 (1932).

[5] Karl Türk, The Ready Remedier, p. 81. Published by the Porcelain Enamel & Mfg. Co., 1931.

[6] Discussion on "Chip-Proof Enamels," *Ceram. Ind.*, **22** [2] 78 (1934).

[7] H. E. Ebright, "Enamel Losses," *Enamelist*, **9** [6] 7 (1932); ref. on p. 34.

[8] E. C. Aydelott and W. H. Pfeiffer, "Enamel Shop Control," *Better Enameling*, **6** [3] 12–17 (1935); *Ceram. Abs.*, **14** [6] 133 (1935).

[9] Recent progress in design studies is notable; see Handbook on Design of Metal Parts for Porcelain Enameling—Pressed Steel Shapes. Published January, 1936, by the Porcelain Enamel Inst., 612 N. Michigan Ave., Chicago, Ill.; also paper by H. H. Holscher, "Design of Sheet-Metal Parts for Enameled Ranges," *Ceram. Ind.*, **26** [2] 124–32 (1936); *Ceram. Abs.*, **15** [5] 144 (1936).

oftentimes be in error by as much as 3 or 4 mils, owing to the sheet-steel thickness tolerance.

The third method for measuring thickness has been by means of a recently developed magnetic gage.[10] This gage[11] will measure the thickness of any nonmagnetic material which has been applied to or laid on flat sheets or plates of steel or iron. Its use in the porcelain-enamel field has been described by the author,[12] and it has achieved wide usage in the industry. The gage operates on a 110-volt, 60-cycle power supply and consists of an indicating unit weighing approximately $7^1/_2$ pounds and a $^1/_2$-pound gage head connected to the unit by cable. It is only necessary to hold the head in contact with the surface to be measured when the dial will give the thickness instantaneously. An area $1^1/_{16}$ inches in diameter is measured. The head can be moved readily to any point on the surface.

The principle of the operation of the gage is described below[13]:

A coil in the gage head and a corresponding balancing coil form two of the arms of a bridge circuit, while two like sections of a differential transformer form the other two arms. The reactance of the coil in the gage head and that of the balancing coil are dependent upon the reluctance of the magnetic circuits which surround them. In the gage head the reluctance of the magnetic circuit is dependent largely upon the air gap or the thickness of enamel between the magnetic shell surrounding the coil and the sheet of steel upon which the enamel to be measured is placed. The balancing coil has an adjustable air gap which can be set at will. With the reactance of the balancing coil fixed by setting the air gap to give a definite unbalance to the bridge circuit for one thickness of enamel under the gage head, differences of reluctance in the gage head give different reactances to this arm of the bridge and corresponding changes in indication of an instrument across the middle points of the two sides of the bridge.

The extent to which the indications are affected by variations in thickness of the steel upon which the enamel is placed is shown by the fact that about 5% difference in indication has been found when using sheets $^1/_{32}$ inch thick from that obtained with sheets $^1/_{16}$ inch thick. The magnetic properties of all grades of sheet steel used for drawing and punching purposes are sufficiently uniform so that errors due to variations in magnetic properties are not appreciable.

To obtain the most accurate readings, it is necessary to adjust the balancing coil with a sheet of steel of the same kind and thickness as the steel of the enameled sheet under the gage head. The accuracy of the gage depends largely upon the uniformity of the surface of the steel upon which the coating to be measured is placed. Rough spots on the steel, especially when one of these comes under the center of the gage head, will cause great variations in the readings obtained.

On perfectly flat surfaces of uniform material, an accuracy of 2% of full-scale value is obtainable for scales of 5 mils or more by calibrating on a sample of the same kind and thickness of steel as that to be measured, as mentioned above. The flatness of steel can not be depended upon to less than 0.1 mil over the area covered by the gage head so that readings can not be obtained with an accuracy which would indicate variations less than that, unless the steel is known to be perfectly flat.

While this gage is intended primarily for making measurements on flat surfaces, it may be calibrated and used on convex, cylindrical, or spherical surfaces. In the case of the convex cylindrical surface, it is necessary to rock the gage head slowly and note the minimum reading. In the case of the spherical surface, it will be necessary to readjust the head unless the radius of the spherical surface is very large compared with the diameter of the gage head. A spherical surface less than six inches in diameter probably can not be measured in this way. In measurements of this nature it is necessary that the bare steel piece over which the thickness standard is placed for setting the gage shall be not only of the same thickness but also of the same shape as that on which the measurement is to be made, and the accuracy obtainable is not quite as great as when measuring on flat surfaces. No accurate measurements can be made on concave surfaces except with a gage head of modified design.

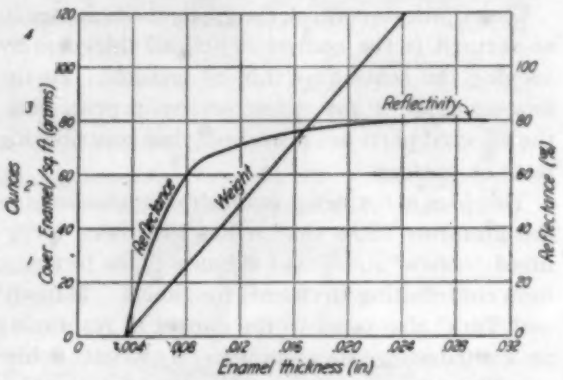

FIG. 1.—Reflectance and weight *vs.* enamel thickness.

In use, the indicating instrument is first adjusted to read correctly with a known thickness of material between the gage head and the sheet of steel of the same kind and of approximately the same thickness as that used with the material being tested. Thickness ranges of 1 to 5, 2 to 10, 5 to 25, 10 to 50, and 20 to 100 mils can be obtained. For wet-process porcelain enamel, a

[10] Information concerning this gage may be secured from the General Electric Co., Lab. Products Section, Schenectady, N. Y.

[11] For description see M. A. Rusher, "Enamel Thickness Gage," *Bull. Amer. Ceram. Soc.*, **14** [11] 365–67 (1935).

[12] H. H. Holscher, "Thickness Gage in Porcelain Enameling," *Better Enameling*, **6** [10] 16–17 (1935); *Ceram. Abs.*, **15** [2] 57 (1936).

[13] M. A. Rusher, private communication.

double-scale instrument with the 2- to 10-mil scale and 10- to 50-mil scale is recommended.

This instrument has many uses in the porcelain enamel plant.[12] Instead of elimination of thick enamel by color differences, which process undoubtedly is inaccurate particularly if enamel color varies even slightly, it is now possible to set a thickness limit and not pass any parts with enamel thickness above that limit. It can also be used to determine whether color variations are due to off-color enamel or to improper thickness. Measurements may be made on dried ware before firing so that more accurate control of the thickness and uniformity of spraying may be secured. The thickness and uniformity of ground coat applied by dipping as well as black-edge or ground-coat reinforcement may also be tested easily. Plant raw materials likewise may be more accurately studied and losses determined.

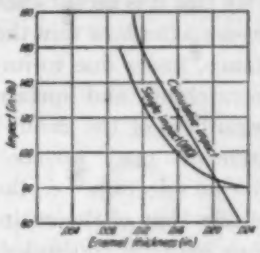

FIG. 2.—Impact *vs.* enamel thickness.

The gage is adaptable to the measurement of the beaded-edge thickness by the following procedure: One edge of the gage head is placed on the bead of enamel with the other edge resting on the adjacent enamel surface. For illustration, a reading is obtained of 19 mils. The head of the gage is then moved about one inch away from the bead and a second reading of 16 mils is obtained. The bead thickness is the sum of the larger reading and the difference between the two readings, 22 mils.

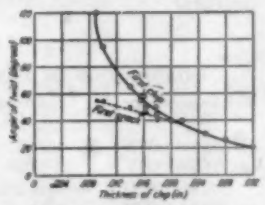

FIG. 3.—Chipping by torsion *vs.* enamel thickness.

III. Enamel Properties vs. Thickness

A laboratory study of the properties of porcelain enamel as related to its thickness has been made. Figure 1 shows the relations between light reflectance (white enamel), weight of enamel applied, and thickness. The curves are shown as starting at 3.5 mils thickness, which is the thickness of the ground-coat enamel. A linear relationship exists between the dried weight of enamel applied and the fired thickness of coating. The reflectance, however, increases at a rate of 15% for each mil of cover enamel applied up to about 8 mils total thickness. It then tapers off until from 16 to 21 mils it increases only about 4%. Reflectivity (reflectance at infinite thickness) of 80% is attained with a thickness of 26 mils or over.

Figure 2 gives a general relationship between impact and thickness. Single impact shows inch-pounds in a single blow to chip, while cumulative starts with a small impact, with additional blows from the next higher setting given every five seconds until failure. All tests are made on steel of 37 mils thickness (20 gage) with hollow backing behind the panel so that bending is secured. Cracking of enamel is not considered failure; a chip must have a dimension of $^1/_8$ inch or more in at least one direction.[14]

Figure 3 shows the relationship between chipping by torsion and enamel thickness. Metal strips, 1 inch by 12 inches, were milled down to $^1/_2$ inch along the central 8 inches, giving a shape similar to tensile-strength test specimens. These were enameled and subjected to increasing angles of twisting. Every two minutes the angle was increased five degrees. The angles of first cracking and first chipping are shown in Fig. 3. Note that an enamel of 20 mils or greater thickness chips as soon as it cracks, while an enamel of 15 mils thickness stands one-third more torsion after cracking before it chips.

IV. Chipping versus Thickness

Studies of chipping within the factory have shown that chipping occurs at points where the enamel is discontinuous in nature, *i.e.*, at corners (47%), at edges (40%), and at holes (13%). At these points the enamel is almost universally thicker than in the body of the part. This is due to the formation of a "bead" which results from the enamel pulling up while it is wet, from spraying or dipping, and from surface tension effects while it is molten during firing. This beading action is largely accounted for by the dipping bead (which in some cases is removed imme-

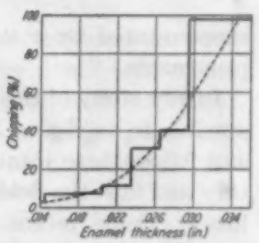

FIG. 4.—Effect of thickness upon chipping.

[14] H. H. Holscher, "Vitreous Enamel Impact Machine," *Jour. Amer. Ceram. Soc.*, **15** [6] 353–57 (1932).

diately after draining of the ground coat) and by the spraying bead which can only be partially reduced by proper consistency control. The bead from firing action is so variable that, in the results reported herein, the thickness is the value taken on the face of the part close to the bead but not including it.

Recently a rather complete study of the relationship between thickness and chipping has been made. This has included losses in the factory

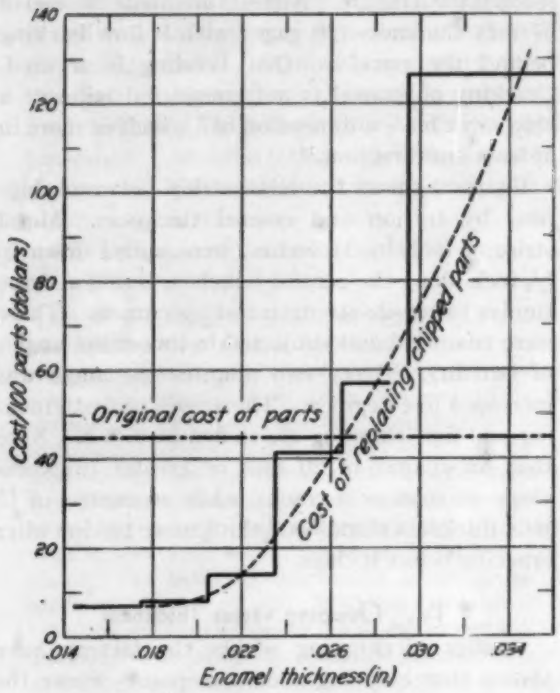

FIG. 5.—Effect of enamel thickness upon cost of chippage replacements.

supplemented by a study of field losses and replacements.

In any study of this nature, it is, of course, impossible to segregate 100,000 parts, for example, and follow these identical parts through the factory and into the field, noting assembly and field losses. Some means of interpretation of data secured on representative samples of the following three groups of parts becomes essential, *e.g.*, (*a*) parts representative of good average enamel department output; (*b*) parts representative of assembly floor losses; and (*c*) parts representative of all field losses.

These samples must be taken at approximately the same time unless it is definitely known that production is uniform over a considerable period of time. This, however, is generally not the case.

It becomes necessary, furthermore, to segregate the losses even further inasmuch as all losses are not due to thick enamel. By this it is meant that certain specific losses occur no matter how thin the enamel may be. For instance, losses due to impact, bending of metal, scratching, and surface defects are predominant regardless of the enamel thickness. Actual measurements made on such losses show that they exhibit no selection, *i.e.*, the average thickness is practically that of the entire good output group. It can only be concluded, therefore, that the impact and bending which result in chipping do so because their magnitude is sufficient to stress the metal beyond its elastic limit.

The distributions of parts by thickness in each of the above three groups are shown in Table I. The data on groups B and C include only those parts for which no normal cause for failure other than thickness could be found (therefore excluding failure by impact, bending, scratching, defects).

TABLE I

DISTRIBUTION OF PARTS BY THICKNESS RANGE

Thickness range (in.)	Group A (%)	Group B (%)	Group C (%)
Below 0.015	47.7	23.1	6.8
0.015–0.017	24.3	29.6	10.8
.018– .020	16.4	17.4	17.6
.021– .023	7.3	11.7	13.5
.024– .026	2.2	7.0	17.6
.027– .029	1.48	4.8	18.9
.030 and above	0.61	6.3	14.9
Av. thickness (in.)	0.0158	0.0189	0.0238

Group A = representative of enamel department good output.
Group B = representative of parts chipped in assembly.
Group C = representative of parts chipped in field.

A simple method to show the proportion of enamel chipped in the various thickness ranges is, for example, to apply the figures in Table I to a production of 100,000 parts, assuming an assembly chippage of 5% and a field chippage of 2%. Such an analysis is presented in Table II.

By combining the thickness ranges below and above a certain set thickness, the results shown in Table III are obtained. This gives data as to losses above the certain thickness selected as compared with losses below this value. The ratios of losses can thus be obtained. It should be noted here that the actual figures given in Tables II and III are in direct proportion to the assumed total

loss of 5% for assembly and 2% for field parts. The ratios which are computed in Table III are independent, however, of these assumptions, being based only on the fact that two-sevenths of all chipping occurs in the field. The actual losses shown in Table II have been plotted in Fig. 4.

TABLE II

EFFECT OF THICKNESS UPON CHIPPING LOSSES

Thickness range (in.)	Total number of parts				Chippage (%)		
	From enamel dept.	Chipped in assembly	Into field	Chipped in field	Assembly	Field	Total
Below 0.015	47,700	1155	46,545	128	2.4	0.3	2.7
0.015–0.017	24,300	1481	22,819	205	6.1	0.9	6.9
.018– .020	16,400	870	15,530	335	5.3	2.2	7.4
.021– .023	7,300	583	6,717	256	8.0	3.8	11.5
.024– .026	2,210	353	1,857	334	16.0	18.0	31.1
.027– .029	1,480	241	1,239	360	16.3	29.1	40.6
.030 and above	610	317	293	282	51.9	96.2	98.2
Total	100,000	5000	95,000	1900	5.0	2.0	6.9

When the data given in Fig. 4 are more completely analyzed by considering the cost of parts, cost of assembly replacements, and the cost of field replacements, an economic balance between acceptance or rejection of parts for use may be made. By taking all of these factors into consideration, the results shown in Fig. 5 are obtained. It is to be noted that starting with 100 parts the cost of which, if immediately scrapped (at exit of enameling department), is approximately $45.00, the cost of replacing those parts which chip would vary from about $7.00, if all the parts had thicknesses below 18 mils, up to $126 if all the parts had thicknesses above 29 mils. Naturally, if it is going to cost more to replace those parts which chip than the cost of all the parts of that thickness, then it is more economical to scrap that particular group of parts immediately. Such an economic balance as shown in Fig. 5 has been determined to be at about 27 mils thickness; *i.e.*, it is more economical to take an immediate scrap loss on all parts which have an enamel thickness of 27 mils or over than to use the parts and pay the subsequent replacement costs.

It must be distinctly understood that this balance of cost is only applicable for certain basic costs of field and assembly replacements, as well as percentage losses, and does not consider such intangible items as customer good will, etc. This balance must be worked out for each individual plant on the basis of its own relative costs and losses, and can not, therefore, be considered universally applicable.

TABLE III

CHIPPING LOSSES ABOVE AND BELOW SET THICKNESS LIMITS

Thickness range (in.)	Total number of parts				Chippage total (%)	Ratios of chippage (thick to thin groups)
	From enamel dept.	Chipped in assembly	Into field	Chipped in field		
0.020 and below	88,400	3506	84,894	668	4.7	5.0
.021 " above	11,600	1494	10,106	1232	23.5	
.023 " below	95,700	4089	91,611	924	5.2	8.4
.024 " above	4,300	911	3,389	976	43.8	
.026 " below	97,910	4442	93,468	1258	5.8	9.9
.027 " above	2,090	558	1,532	642	57.4	
.029 " below	99,390	4683	94,707	1618	6.3	15.6
.030 " above	610	317	293	282	98.2	
Total each pair	100,000	5000	95,000	1900	6.9	

ENGINEERING DEPARTMENT
EDISON GENERAL ELECTRIC APPLIANCE CO., INC.
CHICAGO, ILLINOIS

THE EFFECT OF HYDROCHLORIC ACID AND AMMONIA ON PROPERTIES OF SOME REWORKED BODIES*

By Robert Twells

Abstract

When certain electrical-porcelain bodies are shaped in the bone-dry state, the scrap from the process is finely divided and has a low bulk density. Bodies reprepared from such scrap tend to blister and the glaze tends to contain pinholes after being fired at the maturing temperature. Blistering of the reworked body in firing is not decreased by vacuum treatment of the scrap body slip, and wet grinding definitely increases the blistering. Experiments were conducted in which hydrochloric acid and ammonia were added separately to the body scrap in gradually increasing quantities. The addition of ammonia tended to eliminate blistering of the body and pinholing of the glaze after firing.

I. Introduction

The excess material removed in shaping ceramic bodies is generally salvaged because the amount removed is often high, in some cases as much as 75%. This excess or scrap material is sometimes removed in the leather-hard state and sometimes in the bone-dry state, but in either case it never has quite the same properties as the original body. The process of salvaging the scrap body may be simple or difficult, depending in part upon the characteristics of the body and the state of the scrap. For example, the scrap from a body which is high in clay or has a short firing range is difficult to salvage, and leather-hard scrap can be salvaged more readily than dry dust scrap. The dry scrap material removed during the shaping process (with tool bit or by grinding against a profile grinding wheel) consists chiefly of dust which is removed by suction through a dust collector. It is low in bulk density and difficult to handle and to rewet. Bodies reprepared from such dust scrap have a tendency to blister and the glaze tends to pinhole after being fired at the maturing temperature of the original body. The change in fired properties was thought to be due to a permanent "setting" of the colloidal matter during the drying of the original body, because the scrap bodies are noticeably less plastic. Experiments, however, demonstrated that a dried body which is simply crushed can be reblunged fairly satisfactorily. The finely divided state of the dust scrap and the difficulty of remaking it into a slip then appeared to be the cause of the firing difficulty. In blunging the scrap, a great deal of air is introduced with the dust, but vacuum treatment of the slip does not appear to improve the fired properties. Wet grinding of the dust scrap, rather than blunging, definitely increases the tendency of the reworked body toward blistering.

II. Experimental Work

Inasmuch as the mechanical methods were unsatisfactory, chemical means were tried to disperse and possibly to aid in wetting the dry particles. A series of bodies were prepared to determine the results of adding acid and alkaline electrolytes to the dust scrap of body A which contains a relatively high proportion of clay.

Series 1

The dust was blunged into water containing the respective electrolyte, allowed to stand overnight, and again blunged thoroughly; it was then lawned through a 120-mesh screen and cast into disks in plaster molds. The disks were dried, glazed, and fired to the maturing temperature of the original body.

The fired disks of reworked dust from body A were definitely improved in appearance by the addition of ammonia; 0.5 and 0.75% noticeably improved the glaze and 1.0 and 1.5% further improved the appearance, blistering being almost entirely eliminated at cone $18^3/_4$ down. The addition of 2.0% ammonia produced a body of excellent appearance at cones $18^3/_4$ and 19 down. The bodies containing hydrochloric acid were blistered and the glaze pinholed much like the untreated body, although there was some improvement with additions of 0.75 to 1.5%.

Series 2

A similar experiment was tried using the dust scrap from body B, which is relatively low in

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, March 31, 1936 (White Wares Division). Received May 5, 1936.

TABLE I

COMPOSITION OF BODIES (SERIES 1)

Body No.	AH-5	AH-4	AH-3	AH-2	AH-1	A-0	AN-1	AN-2	AN-3	AN-4	AN-5	AN-6	AN-7
Dust scrap from body A (g.)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
HCl (%)	1.50	1.00	0.75	0.50	0.25	0.00							
0.5 *N* HCl solution (cc.)	825	550	412	275	137	0.00							
NH_3 (%)						0.00	0.25	0.50	0.75	1.00	1.50	2.00	2.50
Ammonia solution 10% NH_3 (cc.)						00	26	52	78	104	156	208	260
Water (cc.)	775	1050	1188	1325	1463	1600	1574	1548	1522	1496	1444	1391	1340

TABLE II

SETTLING BEHAVIOR OF THE BODY SLIPS AFTER LAWNING

Body No.	Clear solution at top of test tube (depths in in.) AH					A-0	AN						
Time (hr.)	5	4	3	2	1		1	2	3	4	5	6	7
0													
5											0.25	0.5	0.37
22	0.18	0.18	0.25	0.25	0.25	0.25	0.12	0.15	0.18	0.15	0.62	1.12	1.0
45	0.21	0.28	0.37	0.37	0.34	0.31	0.28	0.31	0.40	0.28	0.96	1.12	1.06
118	0.28	0.34	0.43	0.40	0.40	0.37	0.62	0.71	0.81	0.71	1.0	1.12	1.06

TABLE III

RESULTS OF FIRING

Firing No. 24 (cone 18¾ down)

Body No.	Appearance of body under glaze	Appearance of glaze
AH-5	Few small blisters	Few pinholes
AH-4	" " "	" "
AH-3	" " "	" "
AH-2	" " "	Many pinholes
AH-1	Large and small blisters	" "
A -0	" " " "	" "
AN-1	Small blisters	Few pinholes
AN-2	Large and small blisters	Surface fairly good; some pinholes
AN-3	" " " "	" " "
AN-4	Not blistered	" " " one pinhole
AN-5	" "	Smooth and clear
AN-6	" "	" " "
AN-7	Two large blisters	" " "
A	Not blistered	" " "

Firing No. 24 (cone 19 down)

AH-5	Some large and small blisters	Few pinholes
AH-4	Few large and small blisters	" "
AH-3	" " " "	" "
AH-2	Badly blistered	Many pinholes
AH-1	" "	Badly pinholed
A -0	" "	" "
AN-1	" "	" "
AN-2	Few large blisters	" "
AN-3	Two large and several small blisters	Somewhat pinholed
AN-4	Two large blisters	Surface fairly smooth
AN-5	One large blister	" " "
AN-6	Not blistered	Surface smooth and clear
AN-7	Few small blisters	Few pinholes
A	Not blistered	Surface smooth and clear

TABLE IV

COMPOSITION OF BODIES

Body No.	B-O	BN-1	BN-2	BN-3	BN-4	BN-5	BN-6	BN-7
Dust scrap from body B (g.)	1000	1000	1000	1000	1000	1000	1000	1000
NH_3 (%)	0.00	0.25	0.50	0.75	1.00	1.50	2.00	2.50
Ammonia solution 10% NH_3 (cc.)		26	52	78	104	156	208	260
Water (cc.)	1600	1574	1548	1522	1496	1444	1392	1340

TABLE V

SETTLING BEHAVIOR OF BODY SLIPS AFTER LAWNING

Body No.		Clear solution at top of test tube (depths in in.) BN						
Time (hr.)	B-0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
5	0.25	0.25	0.31	1.25	1.25	1.06	1.12	1.18
45	0.75	1.12	1.00	1.37	1.25	1.12	1.12	1.25
117	0.87	1.18	1.12	1.31	1.25	1.12	1.12	1.31

clay. The bodies (Table IV) were prepared and the test pieces were cast and fired as in the previous series. Results are given in Tables V and VI.

was slightly less plastic and shaped more slowly by grinding because the dried blanks were harder than those made from body B, the original body. Body BN-1 containing 0.25% ammonia appeared similar to body B in plasticity, drying behavior, and shaping speed. Body BN-3 containing 0.75% ammonia was less plastic than body B but extruded and dried without cracking. The dried blanks were soft and ground to shape rapidly, but the loss from breakage increased.

The test pieces formed by extrusion and grinding were glazed and fired to "cone 18 touching." After firing, bodies BN-1 and BN-3 were satis-

TABLE VI

RESULTS OF FIRING

Firing No. 28 (cone 18 touching; cone 19½ down)

Body No.	Appearance of body under glaze	Appearance of glaze
B -0	Not blistered	Many pinholes, appearance displeasing
BN-1	" "	Smooth and clear
BN-2	" "	" " "
BN-3	" "	" " "
BN-4	" "	" " "
BN-5	Not blistered, but has some shrinkage cracks	" " "
BN-6	" " " " " " "	" " "
B	Not blistered	" " "

Firing No. 32 (cone 19 touching; cone 20½ down)

Body No.	Appearance of body under glaze	Appearance of glaze
B -0	Trace of blistering	Many pinholes
BN-1	Not blistered	Smooth and clear
BN-2	Trace of blistering	Few pinholes
BN-3	" " "	Some pinholes
BN-4	" " "	Few pinholes
BN-5	" " "	" "
BN-6	Shrinkage cracks	Many pinholes
BN-7	" "	" "
B	Not blistered	Smooth and clear

BN-1 is the best of the series.
BN-4 appears slightly better at both temperatures than BN-2 and BN-3.

Body B-0 does not tend to blister as badly as body A-0, but the glaze is pinholed, which makes the appearance displeasing. In the experiment, additions of ammonia tended to eliminate blistering and to improve the appearance of the glaze. The addition of 0.25% ammonia produced the best-appearing body of the series. Additions of ammonia over 1.0% cause the body to have a high shrinkage which might result in other difficulties.

III. Extrusion Experiments

To study the effect of ammonia upon the pugging, drying, and firing behavior of dust scrap, bodies B, B-0, BN-1, and BN-3 were thoroughly prepugged and extruded into blanks one inch in diameter. Body B-0, reblunged from the dust scrap untreated with ammonia, factory in appearance and properties, being similar to body B except in firing shrinkage which was somewhat higher. Body B-0, made from the untreated dust scrap was displeasing in appearance, the glaze being pinholed and the body slightly blistered.

IV. Conclusion

The addition during blunging of small percentages of ammonia to air-floated scrap from some electrical porcelain bodies helps in reworking the material back into a slip, which in turn improves the firing appearance.

The reworked bodies containing hydrochloric acid showed some slight improvement when 0.75 and 1.0% was added.

THE ELECTRIC AUTO-LITE COMPANY
TOLEDO, OHIO

CERAMIC ABSTRACTS

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The bold-face number following the journal name is the volume; the issue number is in brackets, followed by the page numbers, then the year in parentheses.

October, 1936

15—10

Abrasives

Cooling and lubricating liquids for grinding. F. Pachtner. *Oberflächentech.*, **13** [13] 150 (1936).—Emulsions of oil in water are the most suitable solutions for this purpose, but the oils must be of such nature as not to clog up the grinding disks. Finely emulsifying oils, such as Shell oil M2, which takes up water in fine droplets, are the best; a mixing ratio of 1 oil to 60 water is suitable. The water should not be hard, eventually improved by the addition of soda, and should not be hot. The dilution should be 1:50 to 1:70 for grinding Fe, steel, cast Fe and steel, malleable Fe, brass, bronze, Cu, Ni, nickel-silver, Zn, Sn, and Pb, and 1:60 to 1:70 for grinding Al and Al alloys. For grinding electron alloy, a 4% sodium-fluoride solution should be used instead of water. Insulating materials such as hard rubber or ebonite should be ground dry. M.H.

Finishing and measurement of gear wheels. Michigan Tool Co. *Engineering*, **140**, 163–65 (1935).—An account of four recent gear-finishing machines is given. Descriptions of the means for checking and measuring the finished product are included. Illustrated. H.E.S.

Grinding processes: V. Gervase B. Seaton. *Indian Eng.*, **97** [1] 10–12 (1935).—Emery (which differs from corundum merely in impurities), its historic retrospect, source of supply, characteristics, analysis, quarrying, selection, and marketing are described. For Parts I-IV and VI-VIII see *Ceram. Abs.*, **15** [8] 225 (1936). A.P.S.

Synthetic production of the diamond and the liquefaction of carbon. H. Kirchrath. *Elektrowärme*, **6** [7] 222–23 (1936).—Attempts and means to produce artificial diamonds are reviewed. By increasing the solubility of C in Fe and by heating a mixture of powdered coal, iron filings, and liquid CO_2 in a high-pressure vessel by an electric arc, diamonds larger than 0.5 mm. could be obtained. More recently, temperatures up to 3000°C and pressures up to 3000 atmospheres were used by electrically heating carbon or graphite rods. A practical solution has not yet been found for the problem. Uses for artificial diamonds in industry are discussed. 16 references. M.H.

Thirty-five years' development in buffing compositions. R. S. Leather. *Metal Cleaning & Finishing*, **7** [8] 379–84 (1935).—Types of abrasives used in buffing compounds include tripoli, rouges, emery, amorphous silica, unfused alumina, dolomitic lime, and powdered pumice. The principal binders used in buffing compositions are rosin, stearic acid, waxes of various kinds, tallow, and petrolatum. Difficulties in cleaning after buffing are discussed. Factors affecting buffing include (1) the nature of the metal to be buffed, (2) the shape of the piece to be buffed, (3) whether buffing is by hand or on an automatic machine, (4) speed at which lathes are operated, (5) diameter of the buff, and (6) type of buff. Types of compositions are discussed and methods of judging the value of buffing compounds are cited. E.J.V.

PATENTS

Abrasive article. D. E. Webster (Norton Co.). U. S. 2,048,905, July 28, 1936 (April 11, 1934).

Abrasive throwing wheel. V. E. Minich. U. S. 2,049,466, Aug. 4, 1936 (July 5, 1935). A rotor for throwing abrasive at blasting velocities includes spaced rotatably mounted abrasive throwing blades and means for feeding abrasive into the path of rotation of the blades, some of the blades varying in radial length so as to effect even distribution of the thrown abrasive over the work surface, the inner ends of the blades being spaced approximately equidistant from the axis of rotation of the wheel.

Abrasive throwing wheel. American Foundry Equip-

MENT CO. Brit. 449,253, July 8, 1936 (Feb. 23, 1934). Brit. 449,254, July 8, 1936 (May 25, 1934).

Abrasive wheel. H. G. ROBINSON. U. S. 2,047,649, July 14, 1936 (Nov. 6, 1935). A cutting wheel of the character described comprises a thin cutting disk of not over $^1/_8$ in. in thickness and of abrasive material of substantially uniform thickness having a peripheral cutting edge adapted to be worn down during use, the disk having a recess formed in the periphery thereof and a hole extending transversely therethrough in such position that in service the periphery of the disk will wear through into the hole to form a new recess.

Articles of ceramic bonded granular material and method of making. NORTON CO. Brit. 450,260, July 29, 1936 (Jan. 29, 1934).

Automatic sizing mechanism. R. E. W. HARRISON AND C. W. HOPKINS (Cincinnati Grinders, Inc.). U. S. 2,049,611, Aug. 4, 1936 (Sept. 27, 1929).

Centerless grinding machines. A. SCRIVENER. Brit. 449,883, July 15, 1936 (Jan. 10, 1935).

Cylindrical grinding machines. CHURCHILL MACHINE TOOL CO., LTD., AND H. H. ASBRIDGE. Brit. 449,415, July 8, 1936 (Feb. 6, 1935).

Feed mechanism for centerless grinding machines for grinding and polishing work pieces. F. B. HATEBUR. U.S. 2,048,265, July 21, 1936 (April 24, 1935).

Grinding disk. NORTON GRINDING WHEEL CO. Brit. 449,663, July 15, 1936 (Dec. 5, 1934).

Grinding fixture. J. C. DRADER (Michigan Tool Co.). U. S. 2,049,490, Aug. 4, 1936 (May 7, 1930).

Grinding machine. S. J. HARLEY. U. S. 2,047,869, July 14, 1936 (Sept. 22, 1934). E. G. ROEHM (Cincinnati Grinders, Inc.). U. S. 2,048,467, July 21, 1936 (Nov. 5, 1934).

Grinding and polishing machine. A. F. KELM (Kelm & Daniel G. m. b. H.). U. S. 2,047,872, July 14, 1936 (Feb. 23, 1934).

Grinding tool. JOSEF SCHNEIDER (Deutsche Gold- und Silber-Scheideanstalt vorm. Roessler). U. S. 2,049,324, July 28, 1936 (Aug. 15, 1935).

Grinding wheels. NORTON GRINDING WHEEL CO., LTD. Brit. 449,293, July 8, 1936 (Dec. 5, 1934).

Machine for grinding crankshafts. CHURCHILL MACHINE TOOL CO., LTD., AND J. C. JONES. Brit. 450,300, July 29, 1936 (March 3, 1936).

Machine for grinding gear wheels. A. H. ORCUTT (Gear Grinding Co., Ltd.). U. S. 2,048,462, July 21, 1936 (Oct. 23, 1935).

Machine for grinding and polishing curved surfaces. J. A. MOORE. Brit. 449,993, July 22, 1936 (Oct. 25, 1935).

Manufacture of articles of ceramic bonded granular material. NORTON CO. Brit. 449,751, July 15, 1936 (Nov. 8, 1933).

Method of manufacturing crystalline alumina. NORTON CO. Brit. 449,315, July 8, 1936 (Sept. 22, 1933).

Milling and grinding machines for cutting profiled forms. F. Kopp. Brit. 450,016, July 22, 1936 (Nov. 5, 1934).

Polishing machine. EDWARD TURNQUIST (General Motors Corp.). U. S. 2,048,235, July 21, 1936 (May 4, 1932). A machine for polishing the curved surface of a work piece is described.

Preformed abrasive article and process of making. E. S. MERRIAM. U. S. 2,050,112, Aug. 4, 1936 (Sept. 17, 1935). In a process for manufacturing abrasive articles, the steps comprise forming a plurality of green abrasive articles containing abrasive grains, reagents adapted upon subjection to adequate heat to form a vitreous bond between the grains, and a combustible material, placing the green articles in a retort and separating them therein by interposed segregating layers containing a combustion supporting substance, and igniting and burning in the retort the combustible material in the articles and combustion-maintaining substance in the segregating layers to thereby generate the requisite heat within the retort to form a vitreous bond between the abrasive grains in the abrasive articles.

Process of bonding rubber and metal. R. J. REANEY. Brit. 449,528, July 15, 1936 (Oct. 6, 1933).

Process of grinding curved surfaces, and apparatus therefor. J. A. MOORE. Brit. 449,398, July 8, 1936 (Dec. 21, 1934).

Process for producing a garnet abrasive. R. H. RIZOR (Mid-West Abrasive Co.). U. S. 2,050,212, Aug. 4, 1936 (April 22, 1935). The process of producing a garnet abrasive comprises treating garnet grain with a mixture of two or more alkali halides in the presence of oxygen at a temperature between 550°C and 850°C.

Rail-surface grinder. A. W. MALL. U. S. 2,047,591, July 14, 1936 (May 9, 1935).

Roller grinding machine. J. R. KELLER (Black Rock Mfg. Co.). U. S. 2,048,634, July 21, 1936 (March 26, 1935).

Slotted abrasive wheel. H. E. SHERK (Miami Abrasive Products, Inc.). U. S. 2,049,874, Aug. 4, 1936 (Aug. 21, 1933).

Art and Archeology

Archeology of India. STANLEY REED AND FRANCIS LOW. *Indian Yearbook*, **22**, 29–33 (1935–36).—The excavations at Mohenjo-daro in Sind and at Harappa in the Punjab show that 6000 years ago there was a highly developed civilization in India, the equal of those in Egypt and Mesopotamia. The Indian Archeological Survey's publication, *Epigraphia Indica*, is now in the twenty-first volume.

H.H.S.

Art of furnace and chimney tile. A. HIRSCH. *Rev. tech. Luxembourgeoise*, **28** [3] 47–58 (1936).—A series of artistic reproductions of tile and ceramics (with explanations) from museum and private collections in Luxembourg is compiled. Data of age, size, and origin are added.

M.H.

Early New York stoneware jug. Tioughnioga Pottery. MARSHALL DAVIDSON. *Design*, **37** [6] 14–15, 40 (1935).—A unique specimen of pre-Revolutionary New York stoneware, common in the 18th Century, has been acquired by the Metropolitan Museum. Among the few known potters of that day appear the names of Crolins and Remmy, continuing through several generations, in the vicinity of Potter's hill. The name Crolins is always associated with

stoneware. Other New York potters, usually in Cortland or Homer, were Sylvester Blair, Mason and Russell, Bennett and Chollar, Chollar and Darby, and J. Sager and Co. The only collection of Cortland County pottery known is that of Mr. and Mrs. Herbert Smith of Cortland and is illustrated in this article. A description of the making, firing, and salt glazing at one of these potteries is included. E.B.H.

Plants in medieval and ancient art. A. C. Seward. *Discovery*, **17** [197] 133–36 (May, 1936).—A comparative study of the use of leaf, flower, and fruit forms in art and architecture from the earliest times is advocated for botanists and artists. H.H.S.

BOOK

Guide to the Stained Glass of the Victoria and Albert Museum, London. Bernard Rackham. H. M. Stationery Office, London, 1936. xi +141 pp., 64 plates. Price 7s. See also "Glass collections—" *Ceram. Abs.*, **14** [9] 206 (1935). H. H. Stephenson

PATENTS

Designs for:

Bottle. E. W. Fuerst (Owens-Illinois Glass Co.), U. S. 100,691, Aug. 4, 1936 (June 16, 1936). J. H. Funkey (Carr-Lowrey Glass Co.), U. S. 100,368, July 14, 1936 (May 27, 1936). J. F. Goggin (Whitall Tatum Co.), U. S. 100,495, July 21, 1936 (Feb. 1, 1936). Frank McLaughlin (Carr-Lowrey Glass Co.), U. S. 100,708, Aug. 4, 1936 (Dec. 28, 1935).

Bowl. E. W. Newton (Imperial Glass Corp.). U. S. 100,577, July 28, 1936 (May 19, 1936).

Condiment shaker. M. S. Desser (Owens-Illinois Glass Co.). U. S. 100,663, Aug. 4, 1936 (June 1, 1936).

Goblet. A. J. Cunningham. U. S. 100,615 to 100,662, Aug. 4, 1936 (June 9, 1936).

Jar. Frasier Smith (Hazel-Atlas Glass Co.). U. S. 100,720, Aug. 4, 1936 (June 12, 1936). U. S. 100,721, Aug. 4, 1936 (June 15, 1936).

Plate. E. W. Newton (Imperial Glass Corp.). U. S. 100,578, July 28, 1936 (May 19, 1936).

Tumbler. E. W. Newton (Imperial Glass Corp.). U. S. 100,579, July 28, 1936 (May 19, 1936).

Cements

Acid-resisting silicate cements. A. O. Giller. *Bumazhnaya Prom.*, **14** [4] 48–51 (1935); *Chem. Abs.*, **29**, 4915 (1935).—Several cements containing Na_2SiO_3 were prepared and tested. None of them, nor the German Securit cement, resists the action of H_2O, sulfite liquor, or acids. A preliminary treatment of cement specimens with strong acids (HCl, H_2SO_4, or HNO_3) increases their resistance to H_2O and sulfite liquor, and even to 25% H_2SO_4 on boiling. The tests show that reactions with the formation of new compounds in the silicate binder do not take place. The silica gel separated from the water glass acts as a cementing material for the inert fillers in the cement. Na silicate in solution is thus hydrolyzed: $Na_2O{\cdot}nSiO_2 + mH_2O \rightleftarrows 2NaOH + (m-1)H_2O{\cdot}nSiO_2$. Air CO_2, by binding NaOH, shifts the reaction to the right of the equation. This explains the formation of a hardening crust at the external layers of cements. The addition of strong acids accelerates the separation of silica gel in the silicate cements and is capable of completing the reaction in a very brief time: $Na_2O{\cdot}nSiO_2 + H_2SO_4 \rightleftarrows Na_2SO_4 + H_2O{\cdot}nSiO_2$. An increase of temperature, increasing the concentration of Na silicate, is also capable of furthering the irreversible separation of the silica gel.

Flow calorimeter for investigating the heat of setting of cement. W. Swietoslawski. *Przemysl Chem.*, **19**, 183–86 (1935); *Chem. Abs.*, **30**, 2343 (1936).—A flow calorimeter of the new labyrinth type and its application to the study of the reaction of cement with water are described. The plot of heat evolved against time shows the existence of a minimum and of a maximum. When the proportion of water to cement is decreased, the maximum is displaced toward the origin.

Hydraulic setting agents. Progress in the field of hydraulic setting agents. Various kinds of cement. M. Véry. *Tech. moderne*, **28**, 276–79 (1936); abstracted in *Chem. Zentr.*, **i**, 4960 (1936).—A discussion of hydraulic setting agents, their composition, types, and properties, and French cement standards of 1934 is given. M.V.C.

Mechanism of the dehydration of calcium sulfate hemihydrate. Harry B. Weiser, W. O. Milligan, and W. C. Ekholm. *Jour. Amer. Chem. Soc.*, **58** [7] 1261–65 (1936).—Contrary to the conclusions of Linck and Jung, Balarew, Gibson and Holt, and others, the dehydration curve of calcium sulfate hemihydrate gives a definite step, indicating that the compound is a true chemical hydrate and not a zeolite. Contrary to the conclusions of Jung, Ramsdell and Partridge, Caspari, Gallitelli, Onorato, and others, calcium sulfate hemihydrate and "dehydrated hemihydrate" do not have identical structures. The X-radiograms of the two substances are similar, showing that the structures are similar, but the existence of definite characteristic differences between the two patterns indicates that the water molecules in the hemihydrate occupy fixed positions in the lattice. These observations likewise support the view that calcium sulfate hemihydrate is a chemical individual and that the process of dehydration is not zeolitic in character. Illustrated. F.G.H.

Reaction of calcium chloride on Portland cement. Progress report. Paul Rapp and Lansing S. Wills. *Proc. Highway Research Board*, **13** [Part I] 291–99 (1933).—The addition of calcium chloride to Portland cement increases the rate at which heat is evolved to the extent of about 4 cal./g. of cement every 24 hr. It generally decreases the time of set, increases the flow of the concrete mix, and increases the strength of the resulting cement at all ages up to 90 days, the limit to which these tests were carried. M.C.S.

Theory of hardening of Portland cement. A. S. Pantleev and I. L. Lepand. *Tsement*, **3** [12] 11–15 (1935).—The hardening of binding materials based on CaO and SiO_2

depends on aqueous monocalcium silicate that forms in the shape of a colloidal gel during the mixing up of cement with water and afterward assumes a crystalline condition.

P.B. & E.S.

BOOK

Growth and Movement in Portland Cement Concrete. C. G. LYNAM. Oxford Univ. Press, 1934. 139 pp. Index and bibliography. Reviewed in *Indian Concrete Jour.*, **9** [4] 126 (1935). A.P.S.

PATENTS

Cement improver and method. C. R. REX. U. S. 2,048,967, July 28, 1936 (March 21, 1932). The method of producing cementitious material comprises calcining dolomitic rock to leave approximately 5 to 7% thereof carbonate in association with reaction resistant magnesium oxide and reactive calcium oxide, reacting thereon with a solution of magnesium chloride and water, controlling the reaction to keep the temperature from exceeding 105°C and the chloride to be not in excess of 12% of the magnesium oxide to get a mixture of magnesium oxide, magnesium hydrate, calcium hydrate, calcium chloride, and calcium carbonate, and leaching to remove calcium chloride therefrom.

Manufacture of slag cement. GEORGE WITTY. U. S. 2,049,881, Aug. 4, 1936 (Sept. 26, 1935). A slag cement includes, by weight, 100 parts of finely ground mixture of granulated blast-furnace slag, 20 parts of calcium oxide, 10 parts of calcined bauxite, 5 parts of feldspar, 3 parts of calcium chloride, and 2 parts of magnesium sulfate.

Enamel

Barium oxide and zinc oxide as oxides forming enamel. K. KAMP. *Glashütte*, **64** [52] 855–56 (1934).—The properties and effects of barium and zinc oxides in enamels are discussed. The replacement of the zinc by the barium oxides is recommended. See *Ceram. Abs.*, **14** [5] 107–108 (1935). M.V.C.

Behavior of fluorides in enamel in dependence on the enamel composition and its working. W. KERSTAN. *Fachber. V. Deut. Emailfachleute* [Duisburg], No. 1 (Feb., 1934); abstracted in *Sprechsaal*, **69** [18] 254 (1936).—The behavior and volatilization of six fluorides were studied: synthetic and natural cryolite, sodium fluosilicate, sodium fluoride, aluminum fluoride, and fluorspar. There was no difference between the behavior of synthetic and natural cryolite. Aluminum fluoride and sodium silicofluoride decompose chiefly at the beginning of melting and volatilize without change; calcium fluoride volatilizes greatly at high temperature and long duration of melting. Volatilized BF_3 was determined conditionally; H_2F_2 was detected as a waste product of the watery batch. Generally, an increase in fluoride losses occurs with increased temperature and longer melting time. NaF does not sublimate directly as raw material; alkali and fluoride losses were detected, however, when NaF was formed by changing the components of raw materials (soda, fluorspar, and borax). Al and Ca fluorides tend to form oxides. M.V.C.

Effect of neutralizing solutions on ground-coat draining. G. H. MCINTYRE AND P. E. GERDES. *Jour. Amer. Ceram. Soc.*, **19** [9] 253–56 (1936).

Enamel Division report of Committee on Standardization of Tests: A, Developments during 1935 affecting standardized testing in the enamel industry. D. G. BENNETT. *Bull. Amer. Ceram. Soc.*, **15** [8] 276–80 (1936). **B, Need for standard tests for enamels from the viewpoint of the user of enamels.** W. H. PFEIFFER. *Ibid.*, pp. 281–86. **C, Desirable service tests from viewpoint of a commercial enamel laboratory.** G. H. SPENCER-STRONG. *Ibid.*, pp. 286–88.

Frit solubility: I, Comparison of methods of determination and relation of soluble salts to enamel slip consistency. G. H. MCINTYRE AND R. E. BEVIS. *Jour. Amer. Ceram. Soc.*, **19** [9] 249–52 (1936).

High heat-resistant cast iron; new sandblast methods. MARTIN H. KIDDER. *Ceram. Ind.*, **26** [3] 183–84 (1936).—The Mount Vernon (Ill.) Furnace & Mfg. Co. has developed a new type of heat-resisting enameling iron, known as Vernalloy. Comparative tests of it and two other types of iron, to determine heat-resisting power, show it to be superior at the end of 1171 hr. exposure to 1300 to 1600°F to the other two irons after 497 hr. of the same exposure. Using a Wheelabrator Tum-Blast and a special Wheelabrator cleaning room to sandblast the castings has reduced cleaning costs. One company reports savings of 54%. In the Wheelabrator the abrasive is thrown by tangential and centrifugal force onto the work being cleaned, with a patented control device directing all of the abrasive onto the work. Illustrated. E.J.V.

Mechanics of enamel adherence: XII, Chemical and X-ray examination of metallic precipitates from enamels containing iron and cobalt oxides. R. M. KING. *Jour. Amer. Ceram. Soc.*, **19** [9] 246–49 (1936); for Part **XI** see *ibid.*, **18** [10] 319–20 (1935).

Prevention of corrosion in rotary driers. RICHARD L. CAWOOD. *Ind. Eng. Chem., News Ed.*, **13** [5] 105 (1935).—In the drying of enamel frit, contamination, resulting from both corrosion and abrasion of metal, is eliminated by the use of Porox linings. Porox is a pure white synthetic silicate which is vitrified at 2500°F. It withstands the corrosive action of all alkalis and all acids other than hydrofluoric. Standing high in the scale of hardness and being extremely tough, it is resistant to abrasion and is sufficiently refractory to stand up well under temperatures up to 1800°F. It may be subjected to considerable thermal shock without danger of cracking and is high in mechanical strength and low in porosity. Illustrated. F.G.H.

Report on the Sixth Enamel Meeting, 1936. ANON. *Sprechsaal*, **69** [14] 195–96; [15] 208–10 (1936).—Abstracts of the following papers read are given: (1) "Technical developments in enamel operation," by H. J. Karmaus (*Ceram. Abs.*, **15** [9] 270 (1936)); (2) "Effect of opacifiers in wet and powder enamel," by L. Stuckert; (3) "Testing kitchenware enamels for acid stability," by Ernst Rickman (*ibid.*, **15** [8] 231 (1936)); (4) "Practice of enameled shields manufacture," by H. Sasse; (5) "Determination of solubility in highly acid-stable enamel," by Otto Krüger; (6) "Effect of grinding fineness of a ground enamel on its properties," by Dietzel. M.V.C.

Steel for high temperatures. ANON. *Trade & Eng.*, **39**

[870] 11 (1936).—The British Electrical and Allied Industries Research Assn. has found that the addition of molybdenum to carbon steels increases their resistance to temperatures up to 500°C and diminishes their tendency to creep. The resistance to steam at 500°C is not affected by the composition. A.B.S.

Unfused ground sheet-iron enamels. L. VIELHABER. *Emailwaren-Ind.*, **13** [15] 129–30 (1936).—Attempts to use unfused ground sheet-iron enamels are discussed. These enamels have great advantages over ordinary enamels. They are refractory, resistant to heat, and adhere well. Instead of salts combining water, which present difficulties during drying, frits or a new material called Sioglur is introduced into the enamel batch. M.V.C.

Use of stain-proof and stain-resisting enamels. ANON. *Ceram. Forum*, **2** [8] 2 (1936).—Stain-proof and stain-resisting enamels are those which have been known in the past as acid-resisting enamels. Due to the usually high sodium oxide and low boric acid content these enamels have a tendency to settle out and for this reason setting-up agents, such as sodium aluminate and hydrochloric acid, are used. Unless these are used wisely trouble may be encountered, but a properly balanced formula should not offer any great problems. M.C.S.

White ground coats—a dream or vision. ANON. *Ceram. Forum*, **2** [9] 2 (1936).—Up to the present time, attempts to produce white ground coats have been unsuccessful, mainly because of the inability to determine definitely the exact function of the cobalt oxide and to find a compound which serves the same purpose. When more definite knowledge of the effect of cobalt oxide upon the properties of a glass and its adherence to a metal is gained, it will be possible to find a substitute which will permit the use of white ground coats. M.C.S.

BULLETIN

Fluoride investigations: I, Fluorides and fluoride systems. II, Use of fluorides in the vitreous enamel industry. R. M. KING. *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 76 (1933); see *Ceram. Abs.*, **12** [7] 254 (1933). R. F. REA

PATENTS

Enamel-spraying apparatus. ADAM ZISKA AND J. K. MARSHALL (A. O. Smith Corp.). U. S. 2,048,912, July 28, 1936 (March 3, 1932).

Enameling machine. C. S. LARSON (A. O. Smith Corp.). U. S. 2,048,937, July 28, 1936 (Aug. 13, 1932).

Light-colored enamels for direct application to ironware. E. RICKMAN. Brit. 450,349, July 29, 1936 (Jan. 9, 1935).

Tile mounting. E. S. DENK (Porcelain Tile Corp.). U. S. 2,049,427, Aug. 4, 1936 (Dec. 26, 1929). U. S. 2,049,428, Aug. 4, 1936 (Jan. 6, 1930). U. S. 2,049,429, Aug. 4, 1936 (May 15, 1930).

Glass

Absorption of the visible spectrum in glass. M. FANDERLIK. *Sklarske Rozhledy*, **12** [6–7] 86–88; [8] 115–18 (1935).—To determine the spectral transmission or absorption of glass, the Glass Research Station in Hradec Králové, Czechoslovakia, uses a "Domsi" apparatus (from Schmidt & Haensch, Ltd.), based on the spectrophotometric method and combined with a photoelectric registration (Dr. Lange). It consists of a double monochromator, a variable slit, a micrometer screw, a photoelectric apparatus for measuring the intensity of the spectral lines, and a sensitive galvanometer (Kipp & Zonen). The greatest sensitivity of this apparatus is in the yellow of the spectrum. The micrometer screw is gaged with the mercury vapor lamp and hydrogen and helium tubes. The spectral transmission is determined from three measurements at each wave-length: first without the measured glass, second with the glass, and third again without it. The spectrum distances of single measurements to be chosen depend on the character of spectral absorption. If the glass possesses a continuous simple absorption curve, the distances can be larger than if the curve is complicated. The width of the slit depends on the exactness of the determination; as the spectral lines are inflected, variations of the width are limited. The photoelectric cell shows an irregularity in the red end of the spectrum, the galvanometer registering a strong photoelectric stream which decreases and then becomes steady after a time. In consideration of this, only the final stream is registered. Some examples of spectral transmission curves demonstrate the characteristic differences between two red glasses (Cu_2O and Se), two green glasses (CuO and FeO), and between a glass colored with CuO and one with Cu_2O; finally a characteristic curve for neodymium glass (rare earths) is presented. The systematic study of spectral absorption of colored glasses, made in a laboratory oven, leads to the determination of relations between metals, metal oxides, the composition of glass, and the spectral absorption of the same. B.J.V.

Aggregate dimensions of siliceous glasses at high temperatures. P. GILARD AND L. DUBRUL. *Bull. Acad. Roy. Belgique, Cl. Sci.*, **22**, 213–30 (1936); abstracted in *Chem. Zentr.*, **1**, 4196 (1936).—The density and specific heat and, from them, the molecular weight for a greater temperature interval were calculated for three lime-magnesia-soda glasses. M.V.C.

All-electric leer gives uniformly annealed product. MURRAY R. SCOTT. *Ceram. Ind.*, **26** [5] 343–44 (1936).—An electric leer with a continuous roller hearth 50 ft. long was installed by Bausch & Lomb Optical Co., at Rochester, N. Y., for annealing spectacle lens blanks. It is divided into seven zones, each of which is separately controlled. The leer can be brought to temperature in 2 hr. from cold, or in 1 hr. after an overnight shutdown. The temperature control is fully automatic, a Leeds & Northrup Micromax indicating control being used on each of the first five zones. B.J.V.

Application of luminescent screens to glass surfaces. W. H. KOHL. *Can. Jour. Research*, **13** [6A] 126–32 (1935).—An outline is given of the various methods for the application of luminescent screens and their relative merits. Most widespread in use are methods that utilize a liquid binder that enters into a chemical reaction with the glass surface. In other cases, the powder is partially imbedded in the glass surface by a sintering process. The physical

characteristics of the luminescent screen are adversely affected by both of these methods. A process based on the activation of the glass surface by a deposit of sulfur is described. The sulfur coating picks up the luminescent powder in a uniform layer when it is brought into contact with the powder. After being removed by means of a moderate heat treatment, it leaves the screen firmly adhering to the glass surface. Possible mechanisms for the process are briefly discussed. E.J.V.

Bright earth. W. v. Eipp. *Glashütte*, **65** [49] 767–69 (1935).—Glass and its artistic development are dealt with. Illustrated. M.V.C.

British standard specification for colors for signal glasses for railway purposes. Anon. *Jour. Soc. Glass Tech.*, **20** [78] 34–37P (1936).—The specification is reproduced in an abridged form. Copies of the complete specification may be obtained from the British Standards Institution. Price 2s, postage 2d. A.A.

Change in the viscosity of Fourcault glass in dependence on its composition and temperature. M. M. Skornyakov. *Keram. & Steklo*, **12** [5] 33–38 (1936).—The change of the coefficient of viscosity when the glass composition (72.5 SiO_2, 16.2 Na_2O, 9.8 CaO, 0.8 Al_2O_3, 0.2 MgO, 0.2 Fe_2O_3, and 0.3% SO_3) was changed by substitution of SiO_2 by Al_2O_3 (2%), CaO by Al_2O_3 (1.5%), and CaO by MgO (2%) was determined by means of a new viscosimeter. The substitution of SiO_2 and CaO by alumina increases viscosity. The change in viscosity produced by this replacement takes place in the whole temperature interval (1400 to 900°). The replacement of CaO by Al_2O_3 increases viscosity in all temperatures; with increased replacement of CaO by Al_2O_3 at lower temperatures, beginning with 1010°, viscosity increases more rapidly than at higher temperatures. Because of the additive change in viscosity of glasses observed, it is important to determine this effect, under analogous conditions, for a series of other oxide-forming glasses. M.V.C.

Coefficient of friction of yarns. Irving J. Saxl. *Jour. Franklin Inst.*, **221**, 789 (June, 1936).—A method has been devised with which it is possible to determine the coefficient of friction of individual yarns in absolute figures. It consists essentially of paralyzing the constant rotary motion of an unbalanced wheel by the frictional resistance of a piece of yarn loaded at each end with a definite weight. The yarn is in contact with one-half of the carefully standardized surface of the rim of the wheel. The mathematical analysis of the physical principle involved is given. The method also lends itself to the investigation of the frictional characteristics of different weaving and knitting constructions, the determination of the lubricating values of different throwing-oil compounds and various oils, the influence of oxidation upon the lubricating value of oils, and the change in the friction of yarns imparted to them by sizes and other agents. The coefficients of friction for several types of yarns including conditioned yarns have been tabulated. P.T.C.

Comparative data on the work of tank furnaces of various types. M. D. Tamarin. *Keram. & Steklo*, **12** [5] 20–26 (1936).—Data on the operation of various tank furnaces used in Russian glassworks are given. M.V.C.

Decoloration of crystal glass. F. H. Zschacke. *Glashütte*, **66** [13] 233–35 (1936).—The process of decoloration is frequently unsuccessful because of accidents which affect the color of the glass. Tank furnace glass especially is subjected to these accidents. The difficulties occurring with this glass are chiefly due to the use of selenium or its compounds as decolorizers. According to Dietzel (*Ceram. Abs.*, **15** [3] 89 (1936)), selenium can be found in glass in various forms and degrees of oxidation which depend on the different compositions of furnace atmosphere and various reducers and oxidizers in the batch. The decoloration of pot glass, lead, and potassium glass is not so involved; while the effects of furnace atmosphere are less marked, they have other compositions, and different kinds of decolorizers are used. The color tone produced by pigments of heavy metals is affected by the alkalis of the glass. This is also true of nickel oxide with which potassium glass is decolorized. With pyrolusite, the case is different. The power of decoloration of manganese depends on its stage of oxidation: the manganic stage produces violet, while the manganous is colorless. Therefore media, such as saltpeter or sulfate, are added to the melt. Chemical decoloration is discussed in detail. It consists in the transformation of iron contained by the glass into the ferric stage, which is easier to decolorize, and the addition of arsenic which forms a weakly coloring compound with Fe. The testing of crystal or lead glass samples with regard to color purity is mentioned. The danger of overcoloring is pointed out. M.V.C.

Detection and formation of fluoride gall. F. Jochmann. Translated in *Glass*, **13** [6] 248 (1936); for abstract see *Ceram. Abs.*, **15** [9] 271 (1936). M.C.S.

Discussion of "Cast iron for the manufacture of glass bottle molds." B. P. Dudding *et al.* *Jour. Soc. Glass Tech.*, **20** [78] 63–71 (1936).—For the paper discussed see *Ceram. Abs.*, **15** [6] 175 (1936). A.A.

Effect of moisture of sand on the batch and glass. Anon. *Sprechsaal*, **69** [15] 206–208 (1936).—On the basis of tables and diagrams, examples are given showing the great fluctuation in the SiO_2 content of the batch or glass because of the disregard of the actual moisture content of the sand. Great fluctuations in the mean moisture content of the sand are influenced by storing and seasonal variations (summer and winter). M.V.C.

Effect of rate of loading on the breaking strength of glass. L. V. Black. *Bull. Amer. Ceram. Soc.*, **15** [8] 274–75 (1936).

Effect of tank molds and their surface on the quality of pressed blown ware. M. G. Chernyak and M. S. Aslanova. *Keram. & Steklo*, **12** [5] 26–33 (1936).—Gray cast iron molds have a series of defects. Molds of gray cast iron or ordinary steel should be chromium plated. Rust-proof chromium steel should be used for molds for special glasses, such as Fresnel lenses, projector lenses, etc. American and German methods of grinding and polishing glassware are recommended. M.V.C.

Effect of width on the breaking strength of sheet glass. A. J. Holland and W. E. S. Turner. *Jour. Soc. Glass Tech.*, **20** [78] 72–83 (1936).—The effect of width on the modulus of rupture was investigated for specimens cut from flat drawn 26-oz. sheet glass, 10 cm. long (effective length between knife edges 7.6 cm.), 0.26 to 0.295 cm. thick, and varying in width from 0.4 to 1.2 cm. The sides of the specimens tested received different treatments: (1)

ground and mechanically polished, (2) ground and mechanically polished followed by fire polishing, and (3) cut with the diamond and tested with the residual flaws in tension. Progressive increase in the modulus of rupture was found with the decrease in width. For fire-finished specimens, the values of the moduli varied from 1299 to 935 kg./cm.^{2}, when the width increased from 0.4 to 1.19 cm. It was shown that the Karmarsch equation, relating the strength (F) of metallic wires to their diameter, d, *viz.*, $F = a + \frac{b}{d}$, (a and b are constants), applied equally well to the glass specimens tested in which d was regarded as their width. From Griffith's modified equation, values for the "ultimate strength" of glass were calculated. In the case of fire-finished strips this value was 10.0×10^6 kg./cm.^{2} Straight fractures were obtained for widths below 0.8 cm. when the sides were not fire-polished. In the latter case more complex fractures were obtained even for specimens of 0.4 cm. width. See *Ceram. Abs.*, **14** [5] 109 (1935). A.A.

Electrical conductivity of glass: I, Formation of highly resistant layers. H. R. KIEHL. *Physics*, **5** [12] 363–69 (1934).—An effort is made to distinguish more clearly between two types of phenomena which may occur in some glasses: (1) a "reversible absorption" current due to the formation of a high counter e.m.f., and (2) an "irreversible absorption" current due to the formation of a highly resistant layer in the glass. Characteristic curves showing one type of the latter which may occur under certain conditions are given. Although many observers have noticed both phenomena previously, considerable confusion still exists in distinguishing between them. Combinations of both phenomena may be one possible cause of some of the large discrepancies in current-time behaviors reported. A study of the relatively small, slowly decreasing, residual e.m.f. observed upon discharging the sample shows a linear increase of this e.m.f. with increase in temperature for temperatures as high as 150°C. **II, Current increase phenomena with highly resistant layers.** *Ibid.*, pp. 370–73.—With the production of certain types of highly resistant layers in some glasses, increases of current with time similar to those reported qualitatively by several earlier investigators are observed. The nature of these current increases has been studied quantitatively and found to follow, for the cases here studied, the relationship, $\log (I_\infty - I_t) = \log a_1 - b_1 t$, where I_∞ is the maximum value of the current, I_t is the current at any time, t, after application of the field, and a_1 and b_1 are constants. The time, T, for the current to reach its maximum value seems related to the applied voltage by the equation $T = K_1/V - K_2$. The values of the constants K_1 and K_2 seem to decrease with increase in temperature. The time for the current to reach its maximum value decreases rapidly with increase in glass temperature. The possible importance of the phenomena observed in an explanation of the processes involved in the conductivity of glass is suggested, and the need for further investigation is emphasized. No theoretical explanation is given because of the apparent necessity for further investigations. **III, Current-voltage relationships with highly resistant layers.** *Ibid.*, **7** [1] 20–25 (1936).—Some effects upon current-voltage and temperature relationships as caused by the formation of "impregnated" layers in the vicinity of the electrodes are described. For "unimpregnated" samples, Ohm's law appeared to be valid. Upon "impregnation," various current-voltage relationships from $I = AV^N$ to that of Poole were observed, the nature of the function apparently depending upon the characteristics of the layers produced. The Rasch and Hinrichson equation was found valid for fresh samples over the range of temperatures used, but the presence of these layers caused distinct changes in the characteristics of this relationship. The possible influence of such layers upon the electrical properties of glass and other insulating materials at the higher fields and temperatures and their possible effect in causing some of the apparent discrepancies in existing data are pointed out. The importance of much further detailed study of their properties is suggested.

Electrical conductivity of glass in the annealing zone as a function of time and temperature. J. T. LITTLETON AND W. L. WETMORE. *Jour. Amer. Ceram. Soc.*, **19** [9] 243–45 (1936).

End-fired glass furnace designed for ease of firing. THOS. B. HART. *Ceram. Ind.*, **26** [3] 196–98 (1936).—Difficulties ordinarily encountered in end-fired type glass furnaces are described. On a new furnace designed to overcome these difficulties, the melting tank, its crown, and firing ports are "streamlined" for greater efficiency. The novel features in the construction are described in detail with the aid of drawings. E.J.V.

Fibrous glass; a new industry. OWENS-ILLINOIS GLASS CO. *Ceram. Ind.*, **26** [4] 248–50 (1936). E.J.V.

Fundamental problems relating to the strength of glassware. F. W. PRESTON. *Bull. Amer. Ceram. Soc.*, **15** [8] 265–67 (1936).

Glass fiber or wool now produced in Germany. ANON. *Nat. Glass Budget*, **52** [12] 14 (1936). M.C.S.

Glass research institute in Czechoslovakia. W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **20** [78] 30–33P (1936). A.A.

Glass silk: a new material for heat insulation. EDITORIAL. *Martin-Burn House Mag.*, **5** [4] 253–55 (1935).—This new industry has been recently established in Great Britain. A.P.S.

Glass Technical Society meeting. ANON. *Sprechsaal*, **69** [1] 6–10; [2] 22–23 (1936).—A report is given of the 19th Meeting of the German Glass Technical Society held in Berlin, Jan., 1936. Some of the papers read are (1) "Significance of silicate researches for the glass industry," by A. Dietzel; (2) "Work done by technical schools and its use by the glass industry," by L. Springer; (3) "Research by large glass companies," by M. Thomas; (4) "Recoloration of selenium-iron glasses and its significance for the decoloration of glass," by W. Höfler and A. Dietzel; (5) "Dependence of glass grit surface on the type of crushing and sifting and distinguishing it by the optical method," by E. Berger; (6) "Glass in modern buildings," by J. Polivka; (7) "Glass industry and patent literature," by F. Herzfeld-Wuesthoff; (8) "Basic laws of chemical attack on glass," by W. Geffcken; (9) "Using enamel pigments in the glass industry," by H. Kohl (*Ceram. Abs.*, **15** [9] 266 (1936)); (10) "Dependence of density and viscosity on temperature in the Na_2O–SiO_2 system," by G. Heidtkamp and K. Endell (*ibid.*, **15** [9] 272 (1936)); (11) "Changes of permeability of glass with temperatures be-

low and above the transformation point," by A. Klemm; (12) "Work of Otto Schott and its significance in the technology of glass," by G. Keppeler; (13) "New X-ray studies of glasses," by E. Schiebold; (14) "Glass as a commodity," by H. Gretsch. M.V.C.

Ice flowers on glass. RUDOLF LEHMAN. *Glashütte*, **66** [11] 199–203 (1936).—The steps in the production of ice flowers on glass are (1) grinding the glass, (2) coating with glue, (3) air drying, (4) cracking of the glass surface because of the glue, and (5) cleaning the surface. The study of the effects of air moisture and temperature on the formation of ice flowers showed that the process can be shortened considerably. Details are given. Illustrated. See *Ceram. Abs.*, **15** [1] 3 (1936). M.V.C.

Influence of cullet on the reactions occurring during the melting of glass. M. A. BESBORODOV, N. D. ZAVJALOV, AND E. N. ZELIGER. *Jour. Soc. Glass Tech.*, **20** [78] 95–103 (1936).—An investigation was made of the reactions occurring between 500° and 900°C in binary and ternary mixtures of Na_2CO_3, $CaCO_3$, and SiO_2 when heated for 1, 2, and 3 hr. alone and in the presence of 40% by weight of cullet to form a glass of the composition SiO_2 75, CaO 10, and Na_2O 15%. The addition of cullet resulted in the acceleration of the reactions in the batch. Grain size of the materials did not appreciably affect the reactions in mixtures of Na_2CO_3 with SiO_2 or cullet which were complete at 900°. With $CaCO_3$-cullet mixtures, the reactions were almost complete after 3 hr. at 700°. In the ternary mixture the acceleration of the reactions was greatest with cullet of 0 to 0.15 mm. grain size and least with the largest grain sizes 1.00 to 1.50 mm. The rates of reaction of Na_2CO_3 and $CaCO_3$ mixtures were less than the rates of reaction of the individual components heated at the same temperature with cullet. A.A.

Intensification of glassmelting and manufacturing processes at the Misheronskiĭ Glassworks. I. I. KITAIGORODSKIĬ, V. P. SUROVTZEV, I. P. DUZHENKOV, T. N. KASHASH'YAN, AND A. G. BAKULIN. *Keram. & Steklo*, **12** [5] 12–19 (1936).—Details of the reconstruction of the works and of methods of melting are given. M.V.C.

Large chemical apparatus of glass. E. O. SCHULZ. *Glas & App.*, **17** [10] 85–87 (1936).—The mechanical difficulties which form an obstacle to the extensive use of large glass apparatus in the chemical industry are explained, and means for eliminating risks by proper protection from outside forces and correct design with regard to static and dynamic stresses are discussed. 9 references. M.H.

Luminous flame firing makes record at Olean. F. G. SCHWALBE. *Amer. Glass Rev.*, **55** [38] 9 (1936).—Through the use of the luminous flame principle of firing glassmelting furnaces, greater tonnages of glass can be handled, more uniform glass is obtained, a reduction in fuel consumption is effected, and a decrease in the quantity of decolorizer necessary is realized. The fuel saving is effected through more efficient firing within the furnace and this in turn is responsible for the increased tonnage possible. The value of the luminous flame is due, to a large extent, to the radiant heat which is emitted from the radiant carbon. M.C.S.

Making glass wool at Corning. ANON. *Amer. Glass Rev.*, **55** [34] 9 (1936). M.C.S.

Making rock wool at Thorold, Ontario. ANON. *Clay Prod. News*, **9** [6] 5 (1936); see *Ceram. Abs.*, **14** [10] 263 (1935). M.C.S.

Manufacture of glassware in India. STANLEY REED AND FRANCIS LOW. *Indian Yearbook*, **22**, 756–57 (1935–36).—The glass industry is divided between cottage and factory. The factory industry is in its infancy. One plant in the United Provinces has made sheet glass since 1929; other plants make lampware, bottles, and carboys. The chief centers are Bombay, Jubbalpore, Allahabad, Bijhoi, Ambala, Naini, Lahore, and Calcutta. H.H.S.

Manufacture of white colorless glass of greatest purity. ANON. *Sprechsaal*, **69** [16] 238–40 (1936).—The following factors are discussed: (1) furnaces, (2) refractories, (3) composition of the batch, (4) melting, (5) homogenization, and (6) purification. M.V.C.

Modulus of rupture and thermal-shock resistance at elevated temperatures. J. S. GREGORIUS. *Bull. Amer. Ceram. Soc.*, **15** [8] 271–73 (1936).

New materials for glass-metal seals. A. W. HULL, E. E. BURGER, AND L. NAVIAS. Read at New York meeting, Amer. Phys. Soc.; abstracted in *Phys. Rev.*, **49** [8] 647 (1936). J.L.G.

Photoelectric relay reduces losses of bottle-forming process. HAROLD A. MOORE. *Elec. Jour.*, **33** [6] 266 (1936).—A photoelectric relay, used to control the mechanism pushing freshly blown bottles from a conveyer into an annealing furnace, ensures that the pusher does not operate while a bottle is being transferred from the conveyer. In this way jams are prevented. J.C.C.

Preparation of glass helices for use in fractionating columns. WILLIAM G. YOUNG AND ZENE JASAITIS. *Jour. Amer. Chem. Soc.*, **58** [2] 377 (1936).—A method is described for winding and breaking glass helices so that a satisfactory product may be prepared in one-fifth the time previously required. F.G.H.

Properties of glasses for apparatus. E. O. SCHULZ. *Glas & App.*, **17** [12] 101–103; [13] 107–109; [14] 119–20 (1936).—The nature of glass, character and conditions of devitrification, strength at high temperatures, resistance to chemical attacks, and types of chemically resistant glasses are discussed. The molecular forces entering into the shaping of glass, their utilization in glassblowing, and stresses in the glass are explained. Proper cooling methods are described. The times for relieving stress in ordinary alkali-silicic acid glasses by annealing were found to be at 424°C one month, at 446°C one week, at 475°C one day, at 522°C one hour, and at 573°C two minutes. Practices in the manufacture of glass apparatus are briefly described. M.H.

Recommended commercial standard for mirrors. ANON. *Nat. Glass Budget*, **52** [12] 8 (1936).—The Standing Committee of the Division of Trade Standards, National Bureau of Standards, has recommended revisions including a change of title, the elimination of the AA grade, and the designation of three groups as A, No. 1, and No. 2, including the shock or window-glass mirror. M.C.S.

Reports on the latest studies on glass. ANON. *Glashütte*, **66** [8] 130–32; [10] 187–89 (1936).—Abstracts dealing with glass furnaces, their insulation, analysis of glass, testing pressed glass, etc., are presented. M.V.C.

Schott and his work. A memorial lecture. W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **20** [78] 84–94 (1936);

see also *Bull. Amer. Ceram. Soc.*, **15** [5] 169–75 (1936). A.A.

Simultaneous grinding and polishing of both sides of flat glass on the conveyer. A. Kh. Miller. *Keram. & Steklo*, **12** [4] 21–22 (1936).—Illustrated. M.V.C.

Tests of the strength of electric-lamp bulbs with special reference to the time factor. John M. McCormick. *Bull. Amer. Ceram. Soc.*, **15** [8] 268–71 (1936).

Tumbler torture. Harold Schultz. *Factory Management & Maintenance*, **94** [6] 218 (1936).—The Libbey Glass Mfg. Co. subjects glass tumblers to tests for (1) tensile strength, (2) shock resistance, (3) hydraulic pressure, (4) wall strength, (5) resistance to heat shock, (6) wall thickness, (7) color, (8) tolerances, (9) capacity, and (10) weight. The method by which each test is made is briefly indicated. Illustrated. J.L.G.

Viscosity of glasses depending on the temperature and additions. P. E. Frank. *Zhur. Prik. Khim.*, **9** [2] 234–48 (1936).—A description of the measuring apparatus and of its work is given. Experiments were made with Fourcault glass with additions of 3 to 6% by weight of lead, potassium, sodium, boron, barium, zinc, magnesium, aluminium, silicon, calcium, and zirconium oxides at 900 to 1400°. The data obtained are tabulated and shown graphically. In all cases the temperature viscosity coefficient shows maximal values in certain temperature intervals in the limits of 1025 to 1200°. For Na_2O there is a second maximum in the interval 1300 to 1325° which leads to the belief of the existence of certain molecular transformations taking place in liquid fused glass. P.B. & E.S.

Vitreosil immersion heaters. Thermal Syndicate, Ltd. *Ind. Chemist*, **11** [123] 161 (1935).—The properties of Vitreosil, *viz.*, its very low coefficient of expansion and high chemical resistance, render it suitable for heating acid liquors. In addition Vitreosil is an insulator and is an excellent substance for an immersion heater. It can be supplied in units dissipating up to 5 kw. H.E.S.

Waste from the production of ferropotassium cyanide (black) as a substitute for alkalis. V. Yuferov and N. P. Podkopaeva. *Trudui Inst. Khim. Tekh. Ivanovo*, **1**, 90–97 (1935); abstracted in *Chem. Zentr.*, **i**, 4955 (1936).—The use of the waste from the ferropotassium cyanide production in the manufacture of glass is discussed. This waste is composed of 7.9 to 16.7% $Na_2O + K_2O$ besides MgO, Fe_2O_3, Al_2O_3, SiO_2, and some P_2O_5. M.V.C.

Weathering and corrosion of glass by water, acids, and alkalis. V. Dimbleby. *Foundry Trade Jour.*, **52** [978] 325–27 (1935); *Chem. Age*, **32** [824] 330 (1935).—Slow changes taking place on the surface of glass, as in storage, with a loss in brilliance and the appearance of strange patterns on the surface, is known as "weathering." Glasses with high alkali content are prone to weather. Glasses containing zirconia show a remarkable resistance to water, hydrochloric acid, and alkaline solutions. Glasses containing titania or iron oxide behave well except toward caustic alkali. Alumina and zinc oxide show all-around resistance to corrosion, while boric acid is beneficial in quantities not exceeding 10%. The type of test chosen for measuring the extent of attack upon a glass by any reagent should be chosen according to the aim of the investigation, as surface conditioning definitely influences the behavior of vessels or sheets unless the test is prolonged to a stage when such influence is eliminated. The use of glass in powder or grain form eliminates the disturbing influence of surface condition. See "Effect of storage—" *Ceram. Abs.*, **15** [2] 58 (1936). H.E.S.+M.J.H.

BOOKS AND BULLETINS

Drinking Glasses and Wines (Les verres et les vins). Maurice des Ombiaux. Reviewed in *Clarté*, **6** [5] 10–12 (1933).—O. relates the history of utensils used for drinking during the Greek and the Latin civilizations and describes the various glasses now used for drinking wine. Illustrated. R.W.D.

Production and properties of luminescent glasses, with special regard to phosphorous zinc silicates. D. Dobischek. Thesis, Univ. Berlin, 1934. 39 pp. Abstracted in *Referat. Silikatliteratur*, No. 2712 (1936).—The following glasses were studied: (1) calcium fluoride-boric acid glass (1.7 g. CaF_2 + 3.4 g. B_2O_3), very permeable to ultra-violet rays; (2) borate glass (0.8 g. B_2O_3 + 0.9 g. $CaOCO_3$ + 0.8 g. ZnO + 2.1 g. borax + 0.7 g. sodium silicate); (3) lead glass (4.8 g. quartz sand + 3.9 g. PbO + 1.8 g. K_2CO_3 + 0.8 g. borax); (4) potassium glass (3.1 g. quartz glass + 1.8 g. K_2CO_3 + 1.3 g. $CaCO_3$); (5) a soda-lime glass (7.7 g. quartz sand + 2.7 g. Na_2CO_3 + 1.3 g. $CaCO_3$). The first two glasses showed no fluorescence, the others, a blue fluorescence under cathode exposure; under an iron arc, only lead glass fluoresced. Pure zinc silicate added to glass had no effect on fluorescence, but with additions of manganese salts, the fluorescence was activated. The production of phosphorous zinc silicates is discussed in detail. M.V.C.

Stones in Glass (Kamni v Stekle). M. A. Besborodov. Gizlegprom., Leningrad, 1936. 150 pp. Price 3R. B. discusses in detail the questions of the origin and properties of stones in glass and enumerates ways of preventing their formation and eliminating them. The five chief parts dealt with are (1) introduction, including crystalline and vitreous materials, glassmelting, effect of composition on refraction of light, etc.; (2) origin and properties of stones in glass; (3) methods used for their detection and determination; (4) methods used to prevent their appearance or to eliminate them; and (5) stones in glass manufactured in Soviet Russia. See *Ceram. Abs.*, **15** [6] 175 (1936). M. V. Condoide

PATENTS

Apparatus for drawing glass. D. R. Limbers (Pittsburgh Plate Glass Co.). U. S. 2,049,505, Aug. 4, 1936 (July 26, 1935).

Glass body forming machine. Felix Meyer (Kimble Glass Co.). U. S. 2,050,012, Aug. 4, 1936 (Oct. 23, 1933).

Glass cutter. N. H. Klages (G. W. Klages & Son, Inc.). U. S. 2,048,935, July 28, 1936 (March 30, 1935).

Glass feeder. F. L. O. Wadsworth (Ball Brothers Co.). U. S. 2,048,983, July 28, 1936 (July 11, 1933). U. S. 2,049,786 to 2,049,788, Aug. 4, 1936 (Aug. 28, 1933).

Glass-feeding forehearth. W. T. Honiss (Hartford-Empire Co.). U. S. 2,050,211, Aug. 4, 1936 (Oct. 26, 1934).

Glass-to-metal-seal. E. D. McArthur (General Electric Co.). U. S. 2,048,556, July 21, 1936 (Jan. 4, 1934).

Glassworking apparatus and method of forming glass-

ware. G. E. Howard (Hartford-Empire Co.). U. S. 2,047,507, July 14, 1936 (July 27, 1934).

Impulse-type glass feeder. G. R. Haub (Shawkee Mfg. Co.). U. S. 2,047,962, July 21, 1936 (May 13, 1933).

Luminescent glass and method of making. Hellmuth Fischer. U. S. 2,049,765, Aug. 4, 1936 (June 24, 1933). The method described of producing luminescent glass consists in bringing together within a molten body of glass a sensitizing agent consisting of a compound of a metal of a group that consists of manganese, cadmium, cerium, lanthanum, samarium, and yttrium, and a ground material of a group that consists of the oxide, the sulfide, and the selenide of calcium, magnesium, lanthanum, aluminum, strontium, barium, beryllium, zinc, and zirconium, the percentage in which the sensitizing agent is present in the glass being substantially the same as its percentage in a luminescent mass consisting of the ground material and the sensitizing agent and nothing more.

Machines for manufacturing incandescent electric lamps. British Thomson-Houston Co., Ltd. Brit. 449,590, July 15, 1936 (June 30, 1934).

Manufacture of glass sheets. Lambert von Reis (American Bicheroux Co.). U. S. 2,048,830, July 28, 1936 (May 24, 1934).

Means and method for preventing issuance of refractory-contaminated glass from feeder outlets. James Bailey (Hartford-Empire Co.). U. S. 2,050,205, Aug. 4, 1936 (June 15, 1934).

Method and apparatus for conditioning molten glass. C. H. Wright (Libbey-Owens-Ford Glass Co.). U. S. 2,049,600, Aug. 4, 1936 (July 21, 1933).

Method and apparatus for manufacturing bottles, etc., of hollow glassware. L. G. Bates (Hartford-Empire Co.). U. S. 2,047,173, July 14, 1936 (April 4, 1935).

Method and apparatus for manufacturing hollow glassware. E. G. Bridges (Lynch Corp.). U. S. 2,049,422, Aug. 4, 1936 (Feb. 4, 1931).

Method and apparatus for tempering glass articles. Pilkington Bros., Ltd., and J. B. Mitford. Brit. 450,464, July 29, 1936 (Jan. 17, 1935).

Method of making ophthalmic lenses. E. D. Tillyer (American Optical Co.). U. S. 2,049,094, July 28, 1936 (March 10, 1934).

Method of making porous filter bodies of particles of glass. Jenaer Glaswerk Schott & Gen. Brit. 450,193, July 22, 1936 (May 9, 1934).

Method of sealing glass to metal. British Thomson-Houston Co., Ltd. Brit. 449,807, July 15, 1936 (Jan. 4, 1934).

Method and means for tempering glass. H. Perry and A. W. Grotefeld. Brit. 449,602 and 449,864, July 15, 1936 (Oct. 3, 1934).

Ophthalmic lens. E. D. Tillyer (American Optical Co.). U. S. 2,049,095, July 28, 1936 (March 5, 1934). E. D. Tillyer and H. W. Hill (American Optical Co.). U. S. 2,048,304, July 21, 1936 (Dec. 12, 1930).

Process and apparatus for supplying molten glass to forming machines. A. M. Holcombe (Lynch Corp.). U. S. 2,047,913, July 14, 1936 (Aug. 13, 1929).

Process and apparatus for working, with the aid of abrasives, the surfaces of hard materials. Soc. Anon. des Manufactures des Glaces & Produits Chimiques de St.-Gobain, Chauny & Cirey. Brit. 449,835, July 15, 1936 (May 23, 1934).

Process for the manufacture of a sheet composed of spun glass threads. Thuringische Glaswollindustrie vorm. S. Koch Ges. Brit. 449,223, July 8, 1936 (Nov. 16, 1934).

Structural Clay Products

Action of lime on dehydrated kaolin. G. Malquori and F. Sasso. *Ricerca Scientifica*, **2** [9–10] 347–48 (1935).—Lime acts rapidly on dehydrated kaolin at 650°, while the attack of the unheated material is very slow. The difference is rendered more evident if gypsum is added to the system kaolin–lime–water, as it accelerates the fixation of lime. Microscopical examinations (illustrations are given) show the presence of crystals of calcium aluminate and calcium sulfo-aluminate only in dehydrated kaolin. M.V.C.

Brick Industry Week in Zwickau. Anon. *Tonind.-Ztg.*, **60** [15] 188–90 (1936).—Abstracts of papers read at the meeting of the German brick industry held at Zwickau, Jan., 1936, are given. M.V.C.

Coefficient of friction between tires and road surfaces. K. W. Stinson and C. P. Roberts. *Proc. Highway Research Board*, **13** [Part I] 169–88 (1933); see also "Effect—" *Ceram. Abs.*, **15** [2] 62 (1936). M.C.S.

Deformation under load at high temperatures as a method of investigation of paving-brick clays. Ya. A. Sokolov. *Stroitel. Material.*, No. 1, pp. 32–37 (1936).—The investigation of deformation under load at high temperature is valuable for paving-brick clays, aiding to develop an appropriate firing schedule in the sintering stage and to determine an appropriate composition of the batch from different kinds of clay. The character of the deformation is conclusive as to the peculiarities of the behavior of green brick under different firing conditions. The increase of lime content is of definitely negative influence on the interval of sintering of the clay. The method permits the determination of the influence of the molding method on the character of softening and deformation of the sample. P.B. & E.S.

Elastic constants of brick. Raja Ram and Anand Saroop. *Indian Eng.*, **97** [1] 37–42 (1935).—A brief account of apparatus and method of working for the experimental determination of Poisson's ratio and Young's modulus for first-class fired mud brick is given. A.P.S.

Introduction of the dry-pressing method in the brick industry of White Russia. L. I. Kalika and I. P. Raigorodskiĭ. *Stroitel. Material.*, No. 12, pp. 8–12 (1935). P.B. & E.S.

Resistance of building materials to weathering and to frost. S. A. Glebov. *Stroitel. Material.*, No. 10, pp. 59–66 (1935).—Samples of 5 x 5 x 5 cm. are the most appropriate; 15 repeated freezings are sufficient. The freezing temperature must not exeed 10° and the freezing must have a duration of at least 3 hr. Under these conditions volume weight, water-absorbing property, and porosity have no influence. The method can not be replaced by

the sulfate method. The influence of the volume of the chamber and of the volume of the sample at −20° for 5 hr. has not been established. P.B. & E.S.

Skidding characteristics of road surfaces. R. A. MOYER. *Proc. Highway Research Board*, **13** [Part I] 123–68 (1933).—The coefficient of friction of rubber tires on various types of roads was studied. Tests were run on twenty-five types of road material including concrete, asphalt, cinders, brick, gravel, etc. Generally speaking, there is a decrease in the coefficient of friction with an increase in speed, but the reverse of this is true in the case of gravel and cinder roads. The texture of a road surface is an important factor to be considered when skid resistance is to be determined; it was found that the sand-paper texture was the most effective resistor to skidding. M.C.S.

BULLETINS

Barium hydroxide to prevent scumming of ceramic products. J. O. EVERHART, W. C. RUECKEL, AND C. R. AUSTIN. *Ohio State Univ. Eng. Expt. Sta. Circ.*, No. 30, 15 pp. (1935). Free. The use of a mixture of barium hydroxide and barium carbonate was found more effective in reducing scumming of a shale and a surface clay than barium carbonate used alone. R. F. REA

Development of lightweight clay products. G. A. BOLE, assisted by HUSAIN, HALL, AND FOSTER. *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 84, 31 pp. (1934). B. reviews the various methods that have been used in producing lightweight clay products. A method was developed which consisted in incorporating gas bubbles in a plastic clay mass which is subsequently dried and fired. The gas, carbon dioxide, was produced by the action of dilute sulfuric acid on finely ground dolomite mixed with the clay. To cause the bloated mass so produced to set, 6 to 15% plaster of Paris was added. Under certain conditions the plaster of Paris could be eliminated by using a high grog content. The grog absorbed the excess moisture, causing the mass to set. The speed of reaction (rate of gas evolution) was controlled largely by regulating the temperature of the mixture. The slip was thoroughly agitated and poured into molds made of metal coated with paraffine. The paraffine (1) protects the metal from corrosion from the acid and (2) acts as a lubricant when hot, forming a perfect parting between the mold and cast unit. A continuous process of production was developed. No particular difficulty was found in drying or firing the ware. Data are given on crushing strength, permeability, fire resistance, conductivity, sound absorption, etc. Among the uses suggested for this material are insulation (high-temperature and building), acoustic tile (sound insulation), structural uses, and filter tile. It was found that the crushing strength varied with the weight per cubic foot. A product weighing 45 lb./cu. ft. had a crushing strength of 500 lb./sq. in. R. F. REA

Dry press method of making paving brick. J. O. EVERHART. *Ohio State Univ. Eng. Expt. Sta. Circ.*, No. 31, 18 pp. Free. Paving brick having a rattler loss sufficiently low to meet all present-day specifications may be made by the dry-press process. R. F. REA

Mining and grinding methods and costs at the L.W. Camp Co. shale pit. E. J. LINTNER. *Bur. Mines Information Circ.*, No. 6887, 10 pp. Free. Methods and costs of operation at a shale pit at Akron, Ohio, are discussed. L. describes the geology of the region and early shale-mining operations there. R. A. HEINDL

PATENTS

Manufacture of brick. BURBURY BRICK CO., LTD., AND T. SMITH. Brit. 449,307, July 8, 1936 (Jan. 25, 1936).

Masonry wall. J. E. MCPHERSON. U. S. 2,047,882, July 14, 1936 (Feb. 25, 1936). A masonry wall for buildings is constructed of building blocks, some of which are provided on their interior exposed face with integral ribs which, when laid in the wall, are aligned to form parallel recesses between their sides for the reception of bats of heat-insulating material, the ribs being formed with overhanging edges along the sides of the recesses for supporting and holding the insulating material in place while metal lathing is being secured to the outer face of the ribs.

Refractories

Action of alkalis on refractory materials: IV, Action of potassium chloride vapor on refractory materials at 1000°C in the presence of water-vapor and air. F. H. CLEWS, A. CHADEYRON, AND A. T. GREEN. *Refrac. Materials Joint Committee, Inst. Gas Engrs., 26th Rept.*, pp. 24–34 (1935).—Specimens of fireclay, silica, and sillimanite refractories were subjected to the action of potassium chloride vapor in currents of moist air and dry air at 1000°C. The presence of water-vapor increased the attack on the specimens. This increased attack was most marked in the case of the silica brick. In general, the fireclay materials were attacked to a greater extent than the silica materials. For Part I see *Ceram. Abs.*, **15** [7] 207 (1936). R.F.R.

Cast saggers. R. T. MAKHL. *Keram. & Steklo*, **12** [4] 27–31 (1936).—Details of the manufacture of cast saggers are given. M. found that saggers cast under pressure (1) have a more dense body, (2) are more resistant and durable, and (3) may have a higher grog content. M.V.C.

Chemical activity of refractories. J. F. HYSLOP. *Jour. Soc. Glass Tech.*, **20** [78] 61–62 (1936).—A simple test which gives a measure of the chemical activity of a refractory consists in noting the rate at which a standard, high melting point corrodent, such as dolomite, is consumed by a refractory at a particular temperature. The examination of the corroded test piece gives information regarding its texture and bonding. A.A.

Differences between natural and synthetic corundum. ALFRED SCHRÖDER. *Deut. Goldschmiede-Ztg.*, **39**, 90–91 (1936); abstracted in *Chem. Zentr.*, **I**, 4188–89 (1936). M.V.C.

Durability of rotary kiln lining. N. KULIKOV. *Tsement*, **3** [12] 30–31 (1935).—The importance of calculations of the influence of the thermal stress is emphasized and illustrated by examples. P.B. & E.S.

Effect of hydrocarbon gases on refractory material: I, Preliminary study of the effect of methane on refractory materials. E. ROWDEN AND A. T. GREEN. *Refrac. Materials Joint Committee, Inst. Gas Engrs., 26th Rept.*, pp.

34–48 (1935).—Purified methane was passed over fireclay and silica refractory specimens at 795°C. After 37½ hr. no visible effect was found other than discoloration. After 67 hr. the fireclay brick specimens were disintegrated. The silica brick were not disintegrated but only discolored due to the deposition of carbon which readily burned out in an oxidizing atmosphere at a red heat. Carbon spots up to 0.1 in. were found embedded in the disintegrated fire brick. These were believed to have been formed at the iron spots in the original specimens. On heating to a red heat in an oxidizing atmosphere, these spots glowed and burned, leaving reddish brown spots which analyzed high in iron oxide. Mixed with the disintegrated specimens was a large amount of lightweight black powder resembling carbon or soot which, on examination, was found to consist of a mixture of a strongly magnetic iron compound, carbon, and some carbide. The delayed disintegration is thought to be due to the action of a catalyst, and several possibilities are suggested. R.F.R.

Effect of mineralizers on the formation of sinter corundum. D. S. Belyankin and N. J. Filonenko. *Compt. Rend. Acad. Sci., U. R. S. S.*, **2** [2] 146–50 (in German, 150–54) (1935).—Washed alumina (98.86% Al_2O_3) was taken and the casting method was used. Batches containing different percentages (0 to 3) of mineralizers were prepared. The product obtained met fully the requirements put to the German Sinterkorund (impurities not over 0.67%, specific gravity 3.9). Masses without any mineralizer (or with HCl), fired 1 hr. at 1800°, gave a product not differing by their structure and size of grain from the German product. The best mineralizers proved to be $FeCl_3$ and Na_3AlF_6. The lowering of the temperature to 1600 to 1700° is fully sufficient for semiplant investigations.

P.B. & E.S.

Experiments on the behavior of sillimanite mixes on being pressed. F. H. Clews and A. T. Green. *Refrac. Materials Joint Committee, Inst. Gas Engrs., 26th Rept.*, pp. 49–69 (1935).—Experiments in pressing graded calcined kyanite confirm the results of previous investigators in that the decrease in porosity (or increase in bulk density) obtained on applying pressure to granular materials is far more pronounced in the early stages. Thus, there is a limiting pressure above which it is unprofitable to proceed when low porosities are sought. An excessive amount of material passing 200-mesh caused a decrease in final bulk density. Higher bulk densities were obtained when ball clay replaced the 200-mesh sillimanite. Changes in grain size were observed due to the crushing action as the pressure was applied. The rate of application of pressure had no appreciable effect on the final bulk density or degree of crushing. R.F.R.

Fused magnesia. B. Moore and W. L. Patrick. *Ind. Chemist*, **11** [127] 318–20 (1935).—In the electrometallurgical industries, a demand exists for a material which, although possessing an exceedingly low electrical conductivity, is yet a good thermal conductor and which, moreover, remains not only inert to the corrosive actions of atmospheric conditions and of hot metals, but also physically unchanged during succeeding thermal cycles. Such properties are possessed by pure fused magnesia. If magnesite or the magnesia obtained by calcination of it, is heated, *e.g.*, in the electric furnace at a temperature of 3000°C, fused magnesia is obtained which is practically pure beta magnesia (periclase), composed of crystals of the cubic system, octahedral in form. This product is superior to the varieties obtained at the lower temperatures and has a much smaller, nearly negligible, tendency to hydrate, increased electrical resistance, increased thermal conductivity, increased resistance to chemical attack, and increased hardness. H.E.S.

High porosity silica brick: II. F. H. Clews and A. T. Green. *Refrac. Materials Joint Committee, Inst. Gas Engrs., 26th Rept.*, pp. 80–81 (1935).—Test specimens of graded ganister with 30% admixture of anthracite had a porosity of 66.8% and a refractoriness-under-load test of 1450°C under 25 lb./sq.in. More porous materials (70 to 74% porosity) were extremely weak. For Part I see *Ceram. Abs.*, **14** [11] 279 (1935). R.F.R.

Important development in the aluminium industry. A. Troller. *Nature* [Paris], No. 1, pp. 4–8 (1936); abstracted in *Chem. Zentr.*, **i**, 4053 (1936).—A detailed discussion of the method of Séailles for the manufacture of aluminum from bauxite is given. The method is based on the production of $Al_2O_3 \cdot CaO$ by calcining lime and bauxite at 950 to 1100°C, dissolving aluminates in water, separating alumina from lime with carbonic acid, and separating alumina and calcium carbonate. M.V.C.

Jointing cements: IV, Experiments on certain mixtures of possible application as jointing cements for fire brick. F. H. Clews, H. Booth, and A. T. Green. *Refrac. Materials Joint Committee, Inst. Gas Engrs., 26th Rept.*, pp. 69–80 (1935).—The authors continue their previous work with special attention to cements for laying up fire brick. A study was made of various cold-setting additions. For Part III see *Ceram. Abs.*, **14** [11] 280 (1935). R.F.R.

Manufacture of refractories in Australia. Anon. *Chem. Eng. Mining Rev.*, **28**, 324 (June, 1936).—Brick and shapes in high-Al_2O_3, sillimanite, kyanite, SiC, chrome, MgO, bauxite, and diatomaceous earths are being made by the Newbold Silica Firebrick Co. of Sydney, N.S.W. H.H.S.

Minerals and materials used in refractories. Anon. *Refrac. Jour.*, **12** [5] 268 (1936).—A brief description is given of titanium nitride which melts at 3200°C. M.C.S.

Modern furnace applications of refractories and insulation. J. L. Spence and J. W. Craig. *Iron & Steel Can.*, **19** [1] 3–9; [3] 12–16 (1936); see *Ceram. Abs.*, **15** [9] 276 (1936). M.H.

Moscow plants producing silicate brick. K. A. Nokhratyan, S. M. Rosenblit, and S. M. Tzarev. *Stroitel. Material.*, No. 1, pp. 43–44 (1936).—An enumeration of measures undertaken to increase the output is given. P.B. & E.S.

Nonregularity of texture of gas works fireclay refractories and its possible effect on durability. T. F. E. Rhead and R. E. Jefferson. *Refrac. Materials Joint Committee, Inst. Gas Engrs., 26th Rept.*, pp. 89–91 (1935).—The subject is reviewed. R.F.R.

Pictorial methods of recording the texture of refractories and similar materials. T. F. E. Rhead, J. N. Shorrock, and C. L. Evans. *Refrac. Materials Joint Committee, Inst. Gas Engrs., 26th Rept.*, pp. 91–96 (1935).—Several methods of pictorially reproducing the texture of brick are given. R.F.R.

Progress in furnace refractories. J. D. SULLIVAN. *Mining & Met.*, **17** [354] 299–301 (1936).—The changes that must take place in a silica brick during its manufacture are pointed out. Open-hearth bottoms are being made of chrome instead of magnesite brick, with, in some cases, substitution of grain chrome for part of the grain magnesite. Silica brick are the only satisfactory refractories for open-hearth roofs. Mechanical control of combustion by automatic draft and flame reversals and maintenance of a balanced draft over the hearth have effected longer life. Spalling tendencies have been decreased by maintenance of more uniform temperatures throughout due to insulation. Basic and neutral brick are replacing silica in front and back walls where slagging, spalling, and cutting action of the flame have been harmful effects. Ports and bulkheads are being made with high-alumina (70% Al_2O_3) and unburned magnesite or unburned chrome brick. Super-fireclay brick are replacing silica in checker chambers. A good ladle brick is still needed. Recent trends in refractories include low-iron magnesite, unburned magnesite, unburned chrome, forsterite (magnesia and silica in the molecular ratio of 2:1), Kromag, Siemensite cast brick, super-duty fireclay brick made from flint fire clay, and improved high-alumina and silica brick. See *Ceram. Abs.*, **15** [9] 277 (1936). E.J.V.

Proposed specifications for coke-oven refractory materials in the U. S. S. R. YA. O. GABINSKIĬ. *Coke & Chem.* [U. S. S. R.], No. 9, pp. 16–18 (1933); *Chem. Abs.*, **29**, 7034–35 (1935).—The need for only one class of high-quality silica brick is stressed.

Refractories. ANON. *Trade & Eng.*, **38** [803] 54 (1936).—A review of the manufacture of refractories in the British Isles during 1935 is given. Price, appearance, and reputation are still factors of chief importance to users, but physical tests are being increasingly employed, and standard specifications are gaining in popularity. Tunnel kilns with cars and improved methods of drying are being used. Fused (precast) blocks are highly appreciated for special work, but are too costly for general use. Monolithic refractories and refractory cements are increasingly employed. Research is extending rapidly. The formation of a deposit of carbon in the pores of fire brick has received much attention. The addition of a little copper sulfate to the raw clay appears to prevent it. Unfired brick (chiefly of dead-burned magnesite) are found to be advantageous in some electric steel-melting furnaces. Zirconia brick have proved disappointing. Silicon carbide brick are increasingly used for muffles. Mullite brick are gaining in reputation, but many bearing this name are of poor quality. Molding sands are synthesized much more than formerly, and there is a large increase in the scientific control of foundry mixtures. The use of insulating brick in kilns and furnaces is increasing steadily. The need for frank coöperation between manufacturers, users, and investigators is as great as ever. A.B.S.

Refractories: their composition, properties, and applications. D. DIXON. *Steam Engr.*, **5**, 292 (1936); *Trans. Ceram. Soc.*, **35** [6] 49A (1936).—A brief general account is given of the various refractories used in industrial furnaces, the properties which manufacturers endeavor to embody in refractories, and suitable applications for the various refractory materials.

Refractories used in the flint glass industry. W. P. JOHNSON. *Refrac. Jour.*, **12** [5] 231 (1936).—A review of the specifications set up for the refractories to be used in glass pots for melting lead glass is given. The specifications state that (1) two mixtures shall be accepted, one having from 20 to 23% alumina and the other having from 24 to 27% alumina, (2) the iron oxide content shall not exceed 2.5%, (3) the raw clay shall be ground so that 100% passes a 12-mesh sieve and 50% passes 30-mesh, (4) the mixture shall be thoroughly tempered before use, and (5) the amount of grog shall be 20 to 25% of the total mixture and shall be ground to pass a 12-mesh sieve. M.C.S.

Refractoriness-under-load test: II, Experiments on the effect of variation in the height of test pieces. F. H. CLEWS, H. BOOTH, AND A. T. GREEN. *Refrac. Materials Joint Committee, Inst. Gas Engrs., 26th Rept.*, pp. 9–17 (1935).—The cross-section of the test pieces was 1.5 in. on a side while the height varied from 1 to 3.5 in. Two general classes of refractories were tested: fireclay and silica. In the former the difference in temperature of failure did not exceed 40°C, the specimens generally deforming in order, the shortest first and the longest last. In the silica specimens the difference in observed temperatures of failure with different heights of test piece are constant to within experimental error. **III, Experiments on the maintained temperature test.** *Ibid.*, pp. 17–24.—The object of this work was to examine the usefulness of a refractoriness-under-load test which indicates the stability of a specimen of refractory material on heating to and maintaining at a given temperature for a given time under various pressures. For Part I see *Ceram. Abs.*, **14** [11] 282 (1935). R.F.R.

Refractory concrete kiln-car tops give satisfactory service. N. W. THOMPSON. *Ceram. Ind.*, **26** [5] 356–59 (1936).—Refractory concrete has been made possible by the introduction of a high-alumina cement which develops full working strengths 24 hr. after mixing the concrete. Advantages of using refractory concrete for making tunnel-kiln car tops include low cost; reduction in trouble due to wads, sand, etc., working down into the car-top structure; a level smooth surface; and expedition of work. Refractory grog, 50% of which passes a $^1/_8$-in. screen, is mixed 4:1 by volume with Lumnite cement, then wet to a puddling consistency, and worked into the forms desired. Curing water is applied when rubbing a moistened spot leaves the finger clean and is continued every half hour until the concrete is about 18 hr. old. E.J.V.

Saggers with a high grog content. V. A. RUIBNIKOV. *Keram. & Steklo*, **12** [4] 31–34 (1936).—Experiments in the manufacture of rammed saggers with an increased grog content are discussed. M.V.C.

Silicon carbide refractories and their application to boiler furnaces. J. WALKER. *Steam Engr.*, **3** [8] 241–42 (1934); abstracted in *Referat. Silikatliteratur*, No. 713 (1934).—Silicon carbide refractories are excellent material for boiler furnaces. They do not deform at high temperature under load and resist the attack of slag with a low iron oxide or lime content; they are attacked, however, by liquid slag with a high content in basic oxides. Because of their hardness they resist the eroding effect of flue gases. M.V.C.

Slag resistance. W. J. REES. *Claycraft*, **9** [9] 409 (1936).—Various characteristics of refractories which de-

termine their slag resistance are discussed. The most important factors upon which the severity of slagging seems dependent are (1) the rate at which the brick and slag react with each other, (2) rate at which the products of the reaction are removed, (3) rate at which fresh flux contacts the refractory, and (4) the characteristics of the brick, including chemical composition, grain size, porosity, permeability, etc. M.C.S.

Specifications for silica refractory materials for coke ovens. I. B. Peĭsakhzon. *Coke & Chem.* [U. S. S. R.], No. 9, 18–20 (1933); *Chem. Abs.*, **29**, 7035 (1935).—A critical discussion is given. First-class silica brick should have a specific gravity not higher than 2.38 and second class, 2.40.

Stability of linings of rotary kilns at the Novorossiisk plants. S. K. Baev. *Tzement*, **4** [1] 43 (1936).—Raw materials used to obtain high-grade clinker are clinkered at a high temperature (1450 to 1500°C), thus placing the lining under serious working conditions. A high-grade cement and 5 to 6% of volcanic ash have been developed to cover the talc brick lining of the hottest zone. Its use nearly doubled the working period of the kiln. P.B. & E.S.

Stability of new kinds of lining materials. Shekurov. *Tzement*, **4** [1] 40–42 (1936).—The run of a kiln with the sintering zone lined with fired talc brick increased about $1^1/_2$ times. Very good results were obtained also with chrome magnesite brick whose undesirable property is its very high thermal conductivity, requiring the use of special insulating materials. In both cases, sea water was used in the production process. Data of micropetrographic investigations of chrome magnesite brick are appended. P.B. & E.S.

Study on crushing of nonplastics in dry pressing. F. R. Henry. *Jour. Amer. Ceram. Soc.*, **19** [9] 235–39 (1936).

Temperature history and rate of heat loss of an electrically heated slab. Albert B. Newman and Louis Green. *Trans. Electrochem. Soc.*, **66**, 345–58 (1934); *Metals & Alloys*, **6** [10] MA400 (1935); see *Ceram. Abs.*, **14** [8] 198 (1935).

Thermal conductivity of cellular and granular materials. D. Faggiani. *Rend. ist. lombardo sci.*, **68** [11] 523–40 (1935); abstracted in *Physik. Ber.*, **17** [2] 181 (1936).—The heat conductivity is calculated under assumption of irregular distribution of the particles, and the latter are embedded in a carrier not greatly heavier than themselves. The formula agrees well with the heat conductivity of cement embedded in another material and expresses also the change of heat conductivity with the specific weight. M.H.

Thermal insulating materials and their applications. A. C. *Rev. mat. constr. trav. pub.*, No. 319, p. 64B (1936).—The work of A. Clausset is discussed. See *Ceram. Abs.*, **15** [4] 125 (1936). M.V.C.

Tridymitization of silica brick. T. R. Lynam and W. J. Rees. *Refrac. Materials Joint Committee, Inst. Gas Engrs., 26th Rept.*, pp. 81–85 (1935).—The object of this work was to investigate the possibility of "seeding" a silica brick batch with tridymite grown in a slag of known composition. The slags contained silica with additions up to 50% of CaO and 50% Fe_2O_3. Those slags with the best tridymite conversion were used as "seeds." The presence of lime in the silica brick batch was found to favor the inversion of quartz to cristobalite, and the presence of iron brings about an increased inversion to tridymite. See also "Effect of oxides—" *Ceram. Abs.*, **15** [7] 207 (1936). R.F.R.

Use of zoned checkers in hot-blast stoves operating with uncleaned or partially-cleaned gas. S. P. Kinney. *Blast Fur. Steel Plant;* reprinted in *Iron & Coal Trades Rev.*, **129**, 803–804 (1934).—This article describes the "Duoflex" checker arrangement, which offers greater advantages with these gases than the usual checker arrangement. M.H.

BOOKS AND BULLETINS

Highly Refractory Materials. A. K. Freberg and S. V. Babus. Pub. House "Onti," Chief Ed. Office Bldg. Literature, Leningrad, 1935. 172 pp. Price 2R, 50 k. In the world literature there are only a few books dealing with highly refractory materials. Therefore the appearance of this book under review is of interest. The authors' definition of "highly refractory materials" as "products of ceramic manufacture melting at temperatures above 1770°C, *i.e.*, higher than the best grog and Dinas articles, stable against abrupt temperature changes and of considerable slag stability," needs some corrections. The whole text is devoted to high-alumina refractories (corundum, Sinterkorund, hydrates of alumina, minerals of the sillimanite group, and electrofused mullite); refractories of alkaline-earth oxides (calcium oxide, dolomite, magnesite, electrofused magnesite, spinels, forsterite, and olivine); Cr-containing refractories (chromite, chrome-magnesite, Siemensite); ZrO_2-containing refractories; carbon-containing refractories (silicon carbide, silicon, Silundum, Silit, carbon); and articles of highest refractoriness (oxides, nitrides, and carbides). The book is written by two authors engaged in the refractory industry, Freberg as a designer of refractory plants and Babus as an economist. It presents a summary of data scattered in the world literature on highly refractory materials. S. I. Perkal

Researches in dry-press refractories: II, Prevention of pressure cracking. Walter C. Rueckel. *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 82, 36 pp. (1934).—Pressures up to 5000 lb./sq. in. have been used in producing dry-press refractories. Pressure cracking caused by entrapped air can be eliminated by de-airing. Three methods for de-airing were investigated: (1) direct evacuation of mold box, (2) displacing the air in the clay by an easily condensed gas, and (3) double pressing. All three methods were successfully used. The gases used in (2) were ammonia, ethylene, methane, butane, and pentane. Butane was found to give the best results. Commercial tests indicate that forming at high pressures, using one of the three de-airing methods, will not only prevent cracks but will also increase strength and density. Elimination of air during pressing also increases the range of water content permissible for tempering. See *Ceram. Abs.*, **10** [11] 778 (1931). R. F. Rea

PATENTS

Drying and firing arrangement for the linings of ladles, etc., used in steel works. Gutehoffnungshütte Oberhausen A.-G. Brit. 449,739, July 15, 1936 (Nov. 22, 1934).

Firebrick wall construction. J. J. ROBINSON. U. S. 2,047,227, July 14, 1936 (Sept. 17, 1934). In a firebrick wall construction the individual brick members thereof are enclosed in thin sheet expansible fibrous fireproof casings, the casings taking the form of boxes which are readily removable from the individual brick, the brick members in the wall construction being separated only by the casings, which are pressed together by the adjacent brick to form a substantially gas-tight construction.

Highly refractory mass produced by melting. T. R. HAGLUND. U. S. 2,048,263, July 21, 1936 (Aug. 5, 1932). A highly refractory mass produced by fusion of its constituents and having greater strength than pure spinel consists of 17 to 49% MgO, 43 to 71.35% Al_2O_3, 2.75 to 11% SiO_2, and 0 to 8% of impurities consisting of the group CaO, TiO_2, MnO, and FeO, the constituents being so related in the mass that the mass consists of 60 to 92% $MgO{\cdot}Al_2O_3$ spinel for providing the high refractoriness of the mass, and 40 to 8% of other basically saturated combinations of acid and basic oxides having melting points lower than the $MgO{\cdot}Al_2O_3$ spinel but over 1800°C and wherein the MgO and CaO content of the other basically saturated combinations is between 1 to 20% and 45 to 80% and not between 21 and 44% for providing the strength of the mass.

Hot top. E. J. TURNER AND W. A. TURNER (McLain Fire Brick Co.). U. S. 2,049,980, Aug. 4, 1936 (Feb. 6, 1934). U. S. 2,049,981 and 2,049,982, Aug. 4, 1936 (April 3, 1934).

Method of making composite brick. A. M. KOHLER (Babcock & Wilcox Co.). U. S. 2,050,225, Aug. 4, 1936 (May 21, 1932; renewed June 21, 1934). The method of manufacturing a refractory insulating brick includes the steps of mixing powdered refractory and organic particles with a liquid, aërating the mixture to provide minute voids in the finished brick, then molding and deliquidizing the mixture, and finally firing at a temperature imparting the requisite refractory degree and also eliminating the organic particles, leaving minute voids in addition to those created by aëration, while protecting the major portion of the brick from heat intense enough to impart super-refractory qualities to the unprotected portion of the brick.

Method of producing cast refractory. R. C. BENNER AND G. J. EASTER (Carborundum Co.). U. S. 2,048,319, July 21, 1936 (Feb. 25, 1933).

Process of producing refractory bodies. T. R. HAGLUND. U. S. 2,048,861, July 28, 1936 (May 17, 1933; April 16, 1934). A process of producing refractory bodies comprises melting raw materials together in proportions to form a molten mass consisting, after solidification, mainly of crystals of spinels and silicates containing lime, cooling the molten mass and disintegrating it, removing at least mainly the calcium compounds, molding the spinel mass into bodies of desired shape, and firing the bodies.

Silica refractory articles and method of making. R. C. BENNER, H. N. BAUMANN, JR., AND G. J. EASTER (Carborundum Co.). U. S. 2,047,457, July 14, 1936 (March 2, 1933). The process of making refractories comprises forming a mass from a mixture of relatively coarse particles of vitreous silica and levigated alumina and firing the mass at a temperature between 1350 and 1500°C to convert it principally into particles of crystalline silica combined with alumina at their surfaces only, whereby the mass is bonded together.

Vertical retorts for the carbonization of coal, etc. WEST'S GAS IMPROVEMENT CO., LTD., F. J. WEST, AND E. WEST. Brit. 450,333, July 29, 1936 (March 4, 1935).

Terra Cotta

Ceramic mosaic installation failure. JOHN R. KAUFFMAN. *Keram. Tile Jour.*, **8** [5] 4 (1936).—The failure of many tile settings is due to shrinkage or volume change in the setting bed or concrete mortar bed. To overcome such failures, it is recommended that (1) every effort should be made to insure a good bond between the subfloor and the setting bed, (2) the concrete setting bed should be at least 2 in. thick and consist of 1 volume of Portland cement, $2^1/_2$ volumes of sand, and 5 volumes of ground stone, and (3) the tile should be set before the mortar bed has hardened or begun its initial set. M.C.S.

Manufacture of salt-glazed stoneware pipes and fittings: X. A. COULHON. *Brit. Clayworker*, **44** [527] 356–57 (1936).—C. discusses vertical pugmills, preparation of the clay paste by the dry process, and stationary and mechanical continuous driers. **XI.** *Ibid.*, **45** [528] 4–5 (1936).—Mechanical drying, the grinding of raw clays, bucket elevators, storing, and measuring and feeding devices are discussed. **XII.** *Ibid.*, [529] 42–43.—General observations on the early manufacture of pipes and the steps which gradually led to improvement in their manufacture are given. The extruding of the plastic mix, molding the socket and finishing the pipes, and the working of an ordinary helical pipe machine are described. **XIII.** *Ibid.*, [530] 73–74.—An ordinary helical pipe machine and its operation are described. For Parts **VII–IX** see *Ceram. Abs.*, **15** [6] 183 (1936). R.A.H.

Production of engobed facing brick. P. I. GALKIN AND IN. S. ADAMOVA. *Stroitel. Material.*, No. 12, pp. 13–19 (1935).—The clay used in the production of engobed brick must be free of admixtures. Grog of a fineness of 1.5 to 6 mm. must be added to the batch to eliminate cracks during the drying process. The face of the brick can be smooth or rough. Engobes were prepared from different kinds of clay with additions of appropriate mineral dyes and without additions of fluxes. The engobe layer must adhere closely to the surface of the brick, be free from hair seams, and be resistant to frost and weathering influences. A flow sheet of the production process is suggested. P.B. & E.S.

Stoneware for the chemical industry. P. P. BUDNIKOFF. *Sorena*, **1**, 60–74 (1936).—Properties, different uses, and methods of production of stoneware in the chemical industry are described. See *Ceram. Abs.*, **14** [1] 17 (1935). P.B. & E.S.

Tile with "different" appearance developing new market. HUMPHREY BRICK & TILE CO. *Brick Clay Rec.*, **88** [6] 226–27 (1936).—The new Travablock tile are made of buff-firing clay at about 1800 to 1850°F in an oxidizing atmosphere to get an even buff firing. Certain parts of the

kiln are carried 30 to 40° higher, with a reducing fire, flashing the surfaces. By grinding the surfaces, a softness of tone and a texture of air bubbles and pits which add to the beauty of the ware are brought out. Illustrated.

E.J.V.

BULLETIN

Researches on clay and kaolin and the effect of firing temperature on water permeability and frost stability. M. ANDRÄ. Dissertation, Tech. Hochschule, Braunschweig, 35 pp. (1934); abstracted in *Referat. Silikatliteratur*, No. 1742 (1935).—Water permeability, measured by the speed of water infiltration, increased with increased temperature and then decreased. The speed of the movement of water in a body depends on the size of the inner surface and the size of pores. Thinning with quartz sand lowers the effect of the surface on water penetration in all mixes. Frost stability depends on the volume of pores which decreases with increased firing temperature. Quartz sand also lowers the danger of frost. Only samples with 20% porosity were injured by frost. See "Effect—" *Ceram. Abs.*, **14** [11] 284 (1935). M.V.C.

PATENT

Building block and wall structure. H. G. HESS (Hess System, Inc.). U. S. 2,049,907, Aug. 4, 1936 (Nov. 1, 1934).

Whiteware

Casting slip problem in the light of recent research work. E. WETTIG. *Ber. deut. keram. Ges.*, **17** [3] 137–49 (1936).—The development of ideas regarding reactions which take place during the preparation of casting slips is reviewed. W. discusses the scientific viewpoint of this problem and points out the extent to which it agrees with practical experience. Porcelain casting slips are dealt with mainly.

E.J.V.

De-aired and nonde-aired body compared in tableware production. MAYER CHINA CO. *Ceram. Ind.*, **26** [4] 279–80 (1936).—By using a de-aired body along with a nondeaired body, it was found that the greatest difference is apparent in the working properties. The de-aired body is much easier to jigger, and less water is required to secure good working properties; blisters in forming due to air are almost eliminated, giving greater output. No difference in drying was found due to the greater density of the de-aired ware. Results in firing are similar, no variations in glazing procedure are necessary, and the strength of the ware is unchanged. E.J.V.

Determining deformation of flat chinaware. I. YA. YURCHAK. *Keram. & Steklo*, **12** [4] 22–26 (1936); see *Ceram. Abs.*, **14** [3] 75 (1935). M.V.C.

Discolorations in fired kaolin and the manufacture of white porcelain from yellow-coloring components. F. KRAUSS. *Ber. deut. keram. Ges.*, **17** [3] 125–31 (1936).—Fifteen kinds of kaolin were heated successively in oxidizing, neutral, and reducing atmospheres (oxygen from air, nitrogen, and hydrogen) to 750° and then to 1280 to 1300°. In the oxidizing atmosphere all the kaolins had a light color; in a neutral atmosphere slight colorings or discolorations appeared; in a reducing atmosphere all the kaolins became darker, going from silver-gray to blue-gray. On addition of Fe_2O_3, the discoloration was increased. Addition of TiO_2 produced a discoloration, but, on cooling, the clay became white again. Addition of both iron and titanium oxides increased the discolorations to a considerable extent. As a result, it was concluded that the discolorations produced in a reducing atmosphere must be due to an iron-titanium compound. On firing the kaolin samples in a porcelain kiln, these discolorations did not appear because the kiln atmosphere is reducing at first, then oxidizing at the finish. The discolorations appear on glazed porcelain, however, because the oxidizing atmosphere can not act on the porcelain after the glaze has sealed. In an effort to determine the iron-titanium compound responsible for the discolorations, a mixture of Fe_2O_3 and TiO_2 with a large excess of Fe_2O_3 was fired in a reducing atmosphere to 750°, resulting in a deep black product, very sparingly soluble, corresponding in chemical and physical properties to the spinel $FeO \cdot Ti_2O_3$. This spinel is evidently the cause of some of the discolorations in porcelain. In an attempt to apply results to actual practice, small percentages of borax and calcium borate were added to a porcelain body in which the different kaolins were incorporated, but the results obtained were not conclusive in regard to clearing up discolorations. E.J.V.

Firing 1400 dozens of dinnerware per day in a one-man electric kiln. ANON. *Ceram. Ind.*, **26** [4] 297–98 (1936).—The 58 ft. electric decorating kiln at Harker Pottery Co., Chester, W. Va., is of the roller-hearth type, carrying the ware on heat-resisting lightweight alloy trays. It is actually a kiln folded back on itself at the center as the ware moves forward in one direction on two adjacent lines of trays until it reaches the point of maximum temperature, at which point the trays are automatically lowered to the return conveyer bringing them back to the starting place. Positive temperature control is obtained by means of recording and indicating controllers. E.J.V.

Heat and ceramics. P. BREMOND. *Chaleur & Ind.*, **17** [191] 81–88 (1936).—Following an introductory survey of the changes which occur when various types of ceramic materials are fired, the alterations in physical structure which result in vitrification are discussed. These changes may be studied by measurements of porosity, shrinkage, and density. The influence on density of cavities, either internal or connecting with the exterior, is explained in detail. Curves connecting porosity with temperature of firing are given for a number of French porcelains.

J.C.C.

Lead frits and fritted glazes. J. H. KOENIG. *Ceram. Ind.*, **26** [2] 134–36 (1936).—As the best method of reducing the hazard of lead poisoning is to frit all the lead in a glaze, work is being undertaken to develop a single, highly insoluble frit for a standard glaze. The testing of solubility of commercial frits is described, and results obtained are given. The presence of alkalis or boric oxide produces soluble frits, while alumina greatly reduces lead solubility. Tests to be made in a further study are outlined. E.J.V.

BULLETINS

Firing porcelain at lower temperatures. ALBERT

GRANGER. Quatorz Congr. chim. ind., Paris, 1934, Commun. I, 8 pp. (1935); abstracted in *Chem. Zentr.*, i, 2175 (1936).—When porcelain was first produced in Europe according to the method of the Far East, chemical analysis and instruments for measuring temperatures were unknown. Only much later was it determined that porcelain was fired in Europe at much higher temperatures than in the Orient. B. studied the development of European porcelain, the reasons for such high firing temperatures, and attempts to lower them. M.V.C.

Special ware produced at the National Plant of Sèvres. PIERRE BREMOND. Quatorz Congr. chim. ind., Paris, 1934, Commun. I, 4 pp. (1935); abstracted in *Chem. Zentr.*, i, 2175 (1936).—Refractory capillary porcelain pipes, porous filters, and porcelain balls are described. M.V.C.

PATENTS

Artificial teeth. BAKER & Co., INC. Brit. 450,397, July 29, 1936 (Oct. 12, 1934).

Ceramic bath. CHARLES MALLET (Établissements Jacob-Delafon Compagnie Céramique de Pouilly-sur-Saône & Belvoye). U. S. 2,047,481, July 14, 1936 (Sept. 26, 1935). An earthenware bath comprises vertical pillars substantially equal in height to the total height of the bath, a body or tub portion integral with the pillars and comprising walls inclined to the vertical, the walls being of a thickness much less than the width of the pillars.

Closet rim flush. J. R. BEAM (Universal Sanitary Mfg. Co.). U. S. 2,050,152, Aug. 4, 1936 (Aug. 20, 1935).

Fog-type insulator. J. T. LUSIONAN, JR. (Ohio Brass Co.). U. S. 2,048,016, July 21, 1936 (June 2, 1934; Jan. 18, 1935).

Insulation for electrical apparatus. A. O. AUSTIN (Ohio Brass Co.). U. S. 2,048,047, July 21, 1936 (March 5, 1931; Feb. 2, 1933).

Production of steatite ware. STEATIT-MAGNESIA A.-G. Brit. 450,438, July 29, 1936 (Oct. 31, 1934).

Spark plug. C. L. ARNOIS. U. S. 2,048,481, July 21, 1936 (Sept. 12, 1935). HECTOR RABEZZANA AND A. J. BATTEY (General Motors Corp.), U. S. 2,048,028, July 21, 1936 (Nov. 17, 1934). HECTOR RABEZZANA (General Motors Corp.), U. S. 2,048,029, July 21, 1936 (Feb. 6, 1935). B. H. SAVAGE (Savage Research Corp.), U. S. 2,048,297, July 21, 1936 (July 5, 1933).

Teapots, coffee-pots, etc. E. T. EVERTON, LTD., AND A. T. PADMORE. Brit. 450,427, July 29, 1936 (March 28, 1935).

Equipment and Apparatus

Apparatus for determination of the apparent volume and of the volume of voids. J. P. BUWALDA. *Jour. Inst. Petroleum Technologists*, **22** [149] 177–79 (1936). R.F.R.

Apparatus for investigation of cut stones, especially of gems. R. NACKEN. *Zentr. Mineral. Geol. A*, 123–25 (1935). H.I.

Apparatus and method for the rapid and accurate determination of volumes. JEANNE BOBIN. *Chim. & Ind.*, **32** [2] 270–75 (1934).—The principle of the method for the rapid and accurate determination of volume and variations of volume of test pieces of rubber, or other deformable substances commonly used, consists in measuring with great precision, with the aid of a Palmer screw, the difference in the levels of a liquid contained in a cylindrical vessel, hermetically sealed, before and after the immersion of the test piece in the liquid. This difference of levels is registered by the aid of a point fixed on the end of the Palmer screw, a point which is brought in contact with its reflection (obtained by reflection on the surface of the liquid) with remarkable approximation. A body whose volume is known exactly is introduced into the liquid; the change in the level obtained is measured with the point. The operation is repeated from different levels, *e.g.*, from millimeter to millimeter. In this way, an almost perfect calibration is obtained, permitting the determination of the volume of the immersed body up to 1 mm^3. The apparatus is easy to use and there is no evaporation of the liquid during the tests so that very volatile solvents can be used. The sensitivity is such that it is possible to follow the swelling or absorption of a test piece almost continously and to follow the changes due to temperature variations. The apparatus may also be used for the determination of density. M.V.C.

Automatic potentiometer for thermal analysis. R. J. M. PAYNE. *Jour. Sci. Instruments*, **13** [5] 158–61 (1936).—The auxiliary apparatus (including a photocell) required for rendering automatic the working of a particular thermal-curve potentiometer (*Ceram. Abs.*, **15** [4] 129 (1936)) is described. Illustrated. J.L.G.

Bin level signal. BIN-DICATOR CO. *Instruments*, **9** [7] 179 (1936).—Designed for nearly all forms of pulverized and granular materials and for such applications as bins, conveyers, elevators, etc., this device, though just placed on the market, is said to have had four years' service in the largest cement plant where it was originated. It operates on the principle of lateral pressure displacing a diaphragm against a counterweight lever system and operating a mercury switch. This switch may operate a visual or an audible signal, an automatic device for controlling the level, or both an alarm and a controller. Overall diameter $10^1/_4$ in.; projection $6^1/_8$ in. R.W.R.

Capacitrol. J. THOS. RHAMSTINE. *Instruments*, **9** [7] 176 (1936).—This unit operates doors, alarms, etc., on approach of a person or car within 3 ft. of the antenna, which may be from 5 to 50 ft. of rubber-covered wire. R.W.R.

Choice of types of equipment for brick production by the moist method. N. G. TCHIBUNOVSKII. *Stroitel. Material.*, No. 11, pp. 17–29 (1935).—Practical problems of the Soviet Union brick industry are discussed. P.B. & R.S.

Colorimetric analysis by the photoelectric cell. N. STRAFFORD. *Analyst*, **61**, 170–76 (March, 1936).—The advantage of the cell is that color measurements are independent of the human eye. H.H.S.

Comparison of some wet methods used for the fineness test of sands and clays. R. C. HILLS. *Trans. Amer. Foundrymen's Assn.*, **5**, 101–28 (1934).—H. presents the results of an investigation of the better known wet methods for determining the fine-sized particles of clays, mold-

ing sands, soils, and other fine-grained natural or artificial substances. He gives special attention to molding sands, stating that their grain size is their most important property. All the other properties of molding sands, such as strength, permeability, etc., are influenced to a large degree by the grain size. H. made this comparative study of methods in an attempt to determine how closely the several methods checked and how they compare in simplicity of operation. The effects of different electrolytes and the temperature and character of the water used are presented. H.E.S.

De-airing process; modern vacuum and "high-vacuum" methods of working in the technology of plastic bodies. OTTO MANFRED. *Ber. deut. keram. Ges.*, **16** [5] 213–23 (1935).—Reference is made to the relation between the preparation and de-airing of ceramic raw materials. The development of vacuum de-airing of clays and its present state are discussed. A critical analysis of the forming process on the vacuum auger press is given. See *Ceram. Abs.*, **15** [1] 27 (1936); "Vacuum—" *ibid.*, p. 34. E.J.V.

Diesel power in the clay plant. FRED H. SCHWETYE. Presented at Clay Product Plant Operator's Conference, Urbana, Ill., June, 1936; abstracted in *Brick Clay Rec.*, **89** [1] 13 (1936). E.J.V.

Dilatometer for high temperatures. S. PYK, B. STALHANE, AND T. WESTBERG. *Jernkontorets Ann.*, **119**, 401–11 (1935); abstracted in *Chem. Zentr.*, **i**, 4185 (1936). A new dilatometer (a modified Henning model) is described in detail. Examples of measurements of cast iron, steel, and silica brick are given. M.V.C.

Dinnerware placing conveyer with new features. ANON. *Ceram. Ind.*, **26** [3] 176–79 (1936).—The mechanical placing unit of Taylor, Smith & Taylor, at Chester, W. Va., serves a glost tunnel kiln and is designed for the greatest convenience to workmen; all the placing in saggers is done by three men. The unit consists of moving platforms called work cars and moving racks called ware cars. The work car is fitted with a bench which holds the saggers and a platform upon which the placer stands. The ware car holds boards of ware and pins. In a circuit, the saggers of fired ware are placed on the placing unit, saggers are emptied into a tray conveyer, cleaned, and replaced on the line, and the ware is placed in saggers and loaded on the kiln cars. Full details of construction and operation of the unit are given. Illustrated. E.J.V.

Electrical efficiency and economics in plant operation. J. O. KRAEHENBUEHL. Presented at Clay Product Plant Operators' Conference, Urbana, Ill., June, 1936; abstracted in *Brick Clay Rec.*, **89** [1] 13–14 (1936). E.J.V.

Electrostatic dust-count sampler. E. C. BARNES AND G. W. PENNEY. *Jour. Ind. Hyg.*, **18** [3] 167–72 (1936).—A better sampling instrument than the standard Greenburg-Smith impinger should be used for dust counting. The desirable characteristics of a sample and sampler are given. A discussion of centrifugal, thermal, and electrostatic precipitation leads to the conclusion that the electrostatic method has certain advantages over other sampling methods. An electrostatic dust-count sampler and its portable power supply are described in detail. E.J.V.

Fan installations save in power costs. ANON. *Brick Clay Rec.*, **88** [6] 224 (1936).—At the Port Washington, Ohio, plant of the Belden Brick Co., two 6-ft. fans have replaced an 18-ft. fan and a 10-ft. fan with a much lower power cost resulting without any decrease in the manner in which the job is being done. Illustrated. E.J.V.

Glass electrodes for p_H measurements. KURT SCHWABE. *Z. Elektrochem.*, **41** [9] 681–94 (1935).—A comprehensive review of the forms of electrodes, measuring technique, functions of the electrodes, and their application is presented. E.J.V.

Laboratory-size Simpson intensive mixer. NATIONAL ENGINEERING CO. *Ind. Eng. Chem., News Ed.*, **13** [3] 58 (1935).—This mixer, operating on the mulling principle, is equipped with a vacuum for de-airing and heating elements for temperature control during mixing. Operating under a vacuum up to 28 in., interesting results have been obtained in de-airing clay. Production units may be set up with an air-lock for loading and discharging the prepared material directly into an auger in which the material acts as an air-seal, so that the entire system remains under vacuum. Illustrated. F.G.H.

Liquid-level and flow-rate remote-reading systems. C. J. TAGLIABUE MFG. CO. *Instruments*, **9** [7] 182 (1936).—The telemetering system used consists of a pair of self-synchronous motors of standard form, the unique feature of the instrument being radial magnetic coupling between float-operated rotor and rotor of self-synchronous motor. This system obviates stuffing boxes and makes possible perfect sealing. R.W.R.

Low-pressure test gage. FISHER GOVERNOR CO. *Instruments*, **9** [7] 181 (1936).—For indicating pressures less than 1.5 lb./sq. in. where glass U-gages are ordinarily used, this instrument is accurate to $^1/_8$-in. water column. The dial has double calibration from 0- to 35-in. water column, and 0 to 20 oz. per sq. in. R.W.R.

Lubricating greases for industrial use. H. A. MCCONVILLE. *Gen. Elec. Rev.*, **38** [12] 570–73 (1935).—Constitution of grease and types of greases, such as calcium base, sodium base sodium-calcium base, graphite, and zinc base greases, are described. Suitability for definite uses, desirable characteristics, and methods for testing greases are outlined. L.E.T.

Petrographic microscope. E. P. PARTRIDGE. *Crucible*, **20**, 100–101 (1936).—A review of the advantages of the use of the petrographic microscope and a demonstration of the technique involved are given. W.D.F.

Polariscope of high light-transmitting capacity. E. BRUMBERG. *Compt. Rend. Acad. Sci. U.R.S.S.*, No. 1, pp. 35–36 [in German p. 36] (1935).—A simple polariscope of high light-transmitting capacity that can be used for work in the ultra-violet spectrum has been developed. It consists of a small plate of Iceland spar and a transparent lattice consisting of light and dark stripes. For a certain ratio of plate thickness to lattice constant (9:1) no stripes are seen through the crystal. The stripes observed are not interferential, but shade stripes; therefore they can be observed without the aid of an analyzer. No nicols are needed. This polariscope can be substituted in the Cornu polarimeter. P.B. & E.S.

Portable carbon dioxide and temperature indicator. ELLIOT BROTHERS, LTD. *Jour. Sci. Instruments*, **13** [5] 168 (1936).—The instrument employs the Siemen's principle of gas analysis, depending on the thermal conduc-

tivity of CO_2 which is different from that of other gases. Price complete in carrying case is £33, 10s. Illustrated. J.L.G.

Portable recording thermometer. Brown Instrument Co. *Jour. Sci. Instruments*, **13** [6] 198 (1936).—This recording thermometer inclosed in a moisture-proof case uses circular disk charts 8 in. in diameter and good for a 24-hr. record. The sensitive element, a mercury-filled bulb, is mounted outside the case of the instrument. Illustrated. J.L.G.

Pressure compensator for flowmeters. Foxboro Co. *Instruments*, **9** [7] 181 (1936).—This instrument compensates, automatically, for variations in line pressure of fluids, which affect the reading on differential head-type flowmeters, and has been developed for the maker's flowmeters. R.W.R.

Steam power plant problems in the clay plant. Hugo Filippi. Presented at Clay Product Plant Operators' Conference, Urbana, Ill., June, 1936; abstracted in *Brick Clay Rec.*, **89** [1] 12 (1936). E.J.V.

Temperature-control systems and equipment for electric heating. P. H. Clark. *Gen. Elec. Rev.*, **37** [5] 208–17 (1934).—Advantages of electric resistor ovens and furnaces, such as even heat distribution, close temperature control, low maintenance, the need for less floor space, and cleanliness, are stressed. Temperature-control apparatus, mechanical thermostats, liquid-, gas-, and vapor-filled thermostats, thermocouples, millivoltmeters, potentiometers, and pyrometers are described. Illustrated. L.E.T.

Theory and practice of the filtration and drying of ceramic raw materials and bodies. G. Netzel and R. Fischer. *Ber. deut. keram. Ges.*, **17** [4] 210–32 (1936).—The efficiency of a filter is determined by the nature of the material to be filtered, the quantity of solid material in the slip, the temperature of the material, and the speed of revolution of the filter drum. Following a discussion of these factors, an account is given of the development of equipment for the continuous filtration and drying of material for the ceramic industry. Various types of continuous drum filters are described. Illustrated. E.J.V.

Thermoelectrical pyrometers for very high temperatures (1500 to 2000°). A. M. Borzduika. *Zavodskaya Lab.*, **5** [2] 204–206 (1936).—A review of present practice is given. Coal-carbide thermocouples, especially coal-silicon carbide, should be preferred to metallic ones for temperatures over 1500°C on account of their properties (chemical resistivity, thermoelectrodynamic power, etc.). P.B. & E.S.

BULLETINS

Correlation of hydrometer scales. W. Preston, J. A. Reavell, E. A. Alliot, and H. M. Cremer. Abbey House, Victoria St., London, S. W. 1. Price 2s, 6d. Abstracted in *Engineering*, **139** [3616] 474 (1935).—Owing to the multiplicity of the various density scales and systems and the varying natures of their degrees or units, conversion tables become a convenience to enable the exact specific gravity to be stated quickly, or to make comparisons between the results observed with different scales. The various scales, including the Baumé, the new Baumé, and the Dutch and American systems (Balling, Brix, Beck, the Barkometer, Cartier, Marine hydrometer, and Twaddell systems) are considered and compared by conversion tables. The New, the Rational, the Dutch, the American and A. P. I. Baumé scales are also compared. Alcoholometric and sulfuric acid tables are included. H.E.S.

Stoping Methods and Costs. Chas. F. Jackson and E. D. Gardner. *Bur. Mines Bull.*, No. 390, 296 pp. Price 25¢. This bulletin is one of a series of reports dealing with mining methods, practices, and costs. It deals with stoping methods and costs and summarizes the data in earlier publications and those obtained during investigations in the field that apply particularly to stoping. R. A. Heindl

PATENTS

Brick-splitting mechanism. Fritz Koch. U. S. 2,049,704, Aug. 4, 1936 (April 15, 1935).

Electric resistances having a negative temperature coefficient. N. V. Philips' Gloeilampenfabrieken. Brit. 442,348, Feb. 19, 1936 (Aug. 31, 1934).

Grouping of cut brick, etc., from column or stream extrusion mechanisms. E. Frey. Brit. 450,172, July 22, 1936 (Jan. 15, 1935).

Insulator plunging machine. S. L. Moore (Locke Insulator Corp.). U. S. 2,048,558, July 21, 1936 (Nov. 16, 1932).

Method and apparatus for treating and filtering clay slip. D. F. McCormick (Kaolin Processes, Inc.). U. S. 2,049,071, July 28, 1936 (May 12, 1931; Sept. 14, 1933).

Process for the manufacture of detergent, cleansing, emulsifying, softening, and dispersing agents. Chemical Works (formerly Sandoz). Brit. 450,368, July 29, 1936 (June 5, 1934).

Thermocouple alloy. Otto Hermann. U. S. 2,049,443, Aug. 4, 1936 (Feb. 21, 1935). A negative thermocouple alloy consists of nickel and titanium, and a positive thermocouple alloy consists of nickel and copper.

Kilns, Furnaces, Fuels, and Combustion

Addition of water to boiler slacks. A. C. Dunningham and E. S. Grumell. *Jour. Inst. Fuel*, **9** [43] 24–29 (1935).—The addition of water to slack produces a fuel bed of more uniform porosity and with a lower resistance to the passage of air, hence more uniform air distribution. H.E.S.

Application of the Reynolds number for industrial gases. F. Herning. *Gas & Wasserfach*, **79** [15] 232–33 (1936).—For exact calculation of conduits for gases, the exact knowledge of the Reynolds number, expressing the viscosity of the gas, is necessary. The following equation was derived: $R = V \times p/2827 \times D \times \nu_{20} \times (0.88 + 0.006t)$, where R = the Reynolds number, V = the amount of gas in m.³/hr., p = operating pressure in atmospheres,

t = operating temperature in °C, and ν_{20} = the viscosity of the gas at 20°C and 760 mm. Hg, expressed in $m^3./sec.^{-1} \times 10^6$. Some values of ν are as follows:

Air	15.2	Coke-oven gas	27.2±1.0
CO_2	8.1	Producer gas	17.2±0.4
H	106.6	Blast-furnace gas	14.5±0.2
H_2O	1.0	Water gas	24.5

Measuring methods and their errors are briefly explained. M.H.

Application of the theory of sampling to coal sampling. A. B. MANNING. *Jour. Inst. Fuel*, 9 [44] 132–36 (1935).—M. indicates the lines along which a theory of coal sampling (for ash determination) can be developed and how it can be applied to the estimation of the size of sample necessary to ensure a predetermined degree of accuracy in the determination of the ash content. H.E.S.

Bricesco-Harrop car tunnel kiln. T. W. SHOOK. *Clay-craft*, 9 [9] 413 (1936).—A description of the Bricesco-Harrop tunnel kiln and the drier used in firing and drying heavy clayware is given. M.C.S.

Burning Appalachian coals in pulverized form. H. KREISINGER. *Combustion*, 7 [8] 20–22 (1935).—K. discusses the effects of volatile content, fineness of grinding, moisture, and preheat on the ignition of pulverized coal. Factors that insure proper mixing of the fuel particles with the combustion air are also discussed. These points are considered both basically and with special reference to coals from the Appalachian region. H.E.S.

Control chart for interpretation of coal-sampling data. T. W. GUY. *Combustion*, 7 [6] 28–32 (1935).—G. shows how to prepare and use a control chart that will indicate from day to day whether the quality of a given coal is being maintained within the required limits. H.E.S.

Controlled draft conditions give good firing. H. L. LONGENECKER. *Brick Clay Rec.*, 88 [6] 222–23 (1936).—A draft gage measures the intensity of draft or the pressure of air required to burn the coal. Accurate judgment of draft explains why one kiln can be fired with less coal than another. Draft readings should be taken in the stack flue, between the kiln and the damper. In stack-draft plants the time-draft curve will be found to parallel the time-temperature curve very closely. Kiln flues must be kept clean. On a hollow tile kiln careful dampering is important because the tile form a set of chimneys. Methods of firing are discussed. A skilled fireman uses the bag wall as a heat indicator. E.J.V.

Effect of production methods of carbon electrodes on their properties. L. WASSILEWSKI AND A. KOTOWITZ. *Przemysl Chem.*, 18, 618–28 (1934); abstracted in *Chem. Zentr.*, ii, 2857 (1935).—It was found that with decreasing content in coarse grains, the specific resistance reaches a minimum while the resistance to pressure reaches a maximum. Additions of Fe_2O_3, Al_2O_3, and SiO_2 (ash) increase resistance. Resistance also increases with increased duration of firing and lowered shaping pressure; resistance to pressure changes inversely. Resistance and resistance to pressure are lowered with increased temperature of calcining (400 to 1400°). M.V.C.

Feeding height of a grate furnace. A. R. LEYE. *Brennstoff & Wärmewirt.*, 17 [2] 15–21 (1935).—To determine the significance of the feeding height of a grate furnace, the reactions within a glowing coke bed are studied and combustion course curves for a number of values are presented. The feeding height and the level of air intake are found to be the two major factors that permit the stoker to predict the performance of a fuel of known properties. F.P.P.

Flue gas return by the Lutz method. E. PRAETORIUS. *Brennstoff & Wärmewirt.*, 17 [6] 101–103, 116–119 (1935).—Theoretical and practical observations are employed to show the economic importance of methods for mixing returned flue gases with combustion air; the Lutz method is described in some detail. The influence of combustion-chamber temperature, the raising of CO_2 content in the furnace and flue gases, diminution of amount of unburned gases, and utilization of the contaminated air are discussed. Successful applications of the Lutz method have been made in steam plants of paint factories, textile mills and breweries, and in plaster kilns. F.P.P.

Fusibility of coal ash: I, Method for determining the fusibility of coal ash in an oxidizing atmosphere. YOSABURO KOSAKA AND HACHIRO TODA. *Jour. Soc. Chem. Ind. Japan*, 37 [2] 98–101B (1934). **III, Fusibility of Japanese coal ashes in an oxidizing atmosphere.** Y. KOSAKA, H. TODA, AND CHOJIRO KITAGAWA. *Ibid.*, [10] 606–10B. **IV, Fusibility of Japanese coal ashes in a reducing atmosphere.** *Ibid.*, [10] 610–14B. **V, Relation between the chemical composition and the fusibility of Japanese coal ashes.** *Ibid.*, **39** [1] 36–38B (1936).—The relation is shown on curves of a diagram. **VI, Relations between the fusibility and certain characteristics of Japanese coal ash.** *Ibid.*, [1] 38–40B.—The relation between the fusibility and certain characteristics of Japanese coal ash, *e.g.*, solubility in water and acids, alkalinity, and adsorptive power, is shown in a table. M.V.C.

Gas purification. H. HOLLINGS AND W. K. HUTCHISON. *Jour. Inst. Fuel*, 8 [42] 360–71 (1935).—The primary processes of purification are reviewed and questions associated with the storage of the gas are discussed. **Discussion.** ANDERSON *et al.* *Ibid.*, 9 [43] 63–64 (1935). H.E.S.

Melting process of chemically homogeneous masses. E. HERLINGER AND P. BECK. *Sprechsaal*, 66 [10] 161–62 (1933).—Formulas are given showing the sintering process of homogeneous and nonhomogeneous masses in dependence on the dimension of grains composing them. M.V.C.

Methods and instruments of industrial temperature measurements and control: I. R. BOYE. *Eng. Progress*, 17 [5] 117–21 (1936).—The principles of temperature measurement, classification of temperature-measuring instruments, and descriptions of specific types and applications of such instruments are considered in detail. Illustrated. J.L.G.

Relation between elementary and waste-gas analysis of solid and liquid fuels. W. ELLIESEN. *Brennstoff & Wärmewirt*, 17 [3] 36–40, 53–57 (1935).—Various types of fuels may be classified according to their respective "fuel numbers" (X_E) calculated from the elementary analysis of the fuel. Theoretically X_E (fuel number from elementary analysis) and X_A (fuel number from waste-gas analysis) are equal. E. gives formulas for obtaining each in terms of H, O, S, and C, and CO_2, O_2, and CO. F.P.P.

Relation between particle size and duration of melting or sintering of a ceramic mass. E. HERLINGER AND P.

BECK. *Sprechsaal*, **66** [9] 145–47 (1933).—Formulas are developed showing the definite relation between the time necessary for a complete sintering of a homogeneous mass or its fraction and the size of particles composing it. The duration of melting is proportional to the size of the original grain. Examples of calculations are given. M.V.C.

Removal of smoke and acid constituents from flue gases by a noneffluent water process. J. L. PEARSON, G. NONHEBEL, AND P. H. N. ULANDER. *Jour. Inst. Fuel*, **8** [39] 119–52 (1935).—Apparatus, pilot plants, and installations are well diagrammed and illustrated. The apparatus is being used not only for power-plant installations but for rotary salt driers, cement kilns, and blast furnaces as well. **Discussion.** S. L. PEARCE *et al. Ibid.*, [40] 183–99. See *Ceram. Abs.*, **15** [3] 100 (1936). H.E.S.

Research on the hydrogenation of colloidal solution of coal. J. M. PERTIERRA. *Jour. Inst. Fuel*, **9** [43] 16–23 (1935).—The preparation of colloidal solutions of coal with the view to the conversion of coal into liquid fuels is important. See "Colloidal—" *Ceram. Abs.*, **13** [7] 190 (1934). H.E.S.

Speed of fire in Hoffman kilns (experience of the work of the Dolinskaya brick plant, Ukraine). A. F. DMITRENKO. *Stroitel. Material.*, No. 12, pp. 3–5 (1935). P.B. & E.S.

Theoretical consideration of chimney draft. E. F. M. VAN DER HELD. *Brennstoff & Wärmewirt.*, **17** [12] 207–10 (1935).—Mathematical investigation shows that a too wide chimney gives less trouble than one too narrow, as a wide chimney can be lengthened or the heat resistance of its walls increased to permit greater draft, while no simple remedies are available for chimneys too narrow. The most favorable cross-section is the minimum permissible when $T_o/T_k = 11/7$. F.P.P.

Work of the Hoffman kiln at the Dolinskaya brick plant. I. EMELYANENKO. *Stroitel. Material.*, No. 12, pp. 5–8 (1935).

BOOKS AND BULLETINS

Flame. OLIVER C. DE C. ELLIS AND WILLIAM KIRKBY. Methuen and Co., Ltd., London, 1936. 106 pp. Price 3s. Reviewed in *Jour. Amer. Chem. Soc.*, **58** [4] 696 (1936). F.G.H.

Ringelmann smoke chart. RUDOLF KUDLICH. *Bur. Mines Information Circ.*, No. 6888, 3 pp. Free. K. discusses the development and history of the Ringelmann smoke chart and describes its use in this country. R.A.H.

Symposium on Industrial Fuels. American Society for Testing Materials, Philadelphia, Pa., 1936. 70 pp. Price, single copy, 75 cents; ten or more copies, 60 cents. This symposium comprises the following papers: "Coal and Coke, Occurrence, Testing, and Utilization," by A. C. Fieldner; "Industrial Fuel Oils," by H. V. Hume; "Manufactured Gas," by P. T. Dashiell; and "Liquefied Petroleum Gas," by W. H. Bateman. The papers, having the same general outline, are easily comparable. Historical background, magnitude of the industry, future availability of raw materials, possibility of new processes, tests which are applied to the materials, significance of tests, utilization of materials, general economic aspects of the product, and utilization are discussed.

PATENT

Ovens or kilns. A. J. CAMPBELL. Brit. 443,147, March 4, 1936 (July 20, 1934).

Geology

Chemical and optical relations in the brittle mica group. G. KOCH. *Chem. Erde*, **9**, 453–64 (1935). H.I.

Concentration of quartz sands by means of the modified Adams method. I. I. KITAIGORODSKIĬ AND G. G. SENTYURIN. *Keram. & Steklo*, **12** [4] 26–27 (1936).—A modified Adams method for purifying quartz sand was used. The modification consisted in treating washed sand in an $FeSO_4 \cdot 7H_2O$ solution with 5% H_2SO_4. The results are tabulated. A 2-hr. treatment eliminated 90% of the iron, and a 20-hr. treatment eliminated 98% of the iron content. M.V.C.

Determination of total content of salts in clays. A. AVGUSTINNIK. *Stroitel. Material.*, No. 1, pp. 38–40 (1936).—After heating a weighed sample for $^1/_2$ hr. at 50 to 60° with a double amount of distilled water, water is added to the slurry, and the latter is stirred for $^1/_2$ hr. The clay suspension obtained is filtered through a ceramic filter (Chamberlain bacteriologic filter). Two determinations can be made in a working shift. P.B. & E.S.

Elasticity and plasticity of rocks and artificial stones. R. H. EVANS. *Proc. Leeds Phil. Lit. Soc.*, **3**, 145–58 (1936); abstracted in *Chem. Zentr.*, **i**, 4351 (1936).—A series of rocks, such as granite, marble, sandstone, schist, and cast mortar, were studied with respect to their elastic and plastic properties, especially in their dependence on time and relationship between tensile strength and resistance to pressure. M.V.C.

Fluidity, lubrication, and thixotropy of bentonite suspension. OSAMU KIMURA. *Jour. Chem. Soc. Japan*, **56**, 1346–52 (1935); *Chem. Abs.*, **30**, 1195 (1936).—The yield value of Korea bentonite suspension (1.35%) is maximum when its NaCl content is 100 to 200 millimolecules. The suspension then shows a minimum static coefficient of friction.

Genesis of mottled clays in some deposits of the Kiev region. A. V. LIPKOVSKA. *Geologichnuĭ Zhur.*, **2** [2] 97–122 (1935). M.V.C.

Improvements in feldspar preparation. CARL WILKE. *Ind. Eng. Chem., News Ed.*, **13** [4] 71 (1935).—In the dressing of German feldspar ores, a flotation process using sodium oleate and carbolic acid has been successful. The feature of the process is "reversed" flotation, *i.e.*, the worthless material (micaceous iron ore) is floated while the salable product sinks as a purified residue. The coming process for treating German feldspar ore that has a relatively high mica content is a combination of magnetic separation (for particle sizes of 0.1 to 0.3 mm.) and flotation. F.G.H.

Is there connection between slope-incline and clay-soil chemistry? R. SEIFERT *et al. Mitt. preuss. Versuchanst. f.*

Wasserbau & Schiffbau, No. 20, 34 pp. (1935); abstracted in *Zentr. Gewerbehyg. Unfallverhüt.*, **23** [1] 21 (1936).—Six research men for the Prussian Hydraulics and Ship-Building Works, located in South Berlin, emphasize the physical character of clay as estimated by its water-content, particle fineness or form not conditioning its water combination. Chemical processes have been established as chiefly determining it. Its clay soil content must be known in order to know its solubility. These authors had at hand exact results of their studies of different kinds of clay soil. They investigated the dependence of shearing strength upon the chemical nature of clay crystals, water-combination, and admixtures. Clay composition is not indisputably established petrographically. Roentgenoptic research only attains it. Colloid-chemical investigation is on that account significant, as it reveals (clears up) the water permeating the soil. Clay surface materials have combining ability with the water content of the soil. These soil studies included characteristic consideration of the shearing strength, since upon it depend the productive strength of the slope-angle, the pressure against supporting walls, and the carrying power or load fundamental in construction. Particle content is just as important as water content and plasticity. Clay soil content is not, however, completely cleared up. Whether it comes into contact with water under formative conditions or after definite load requires further investigation. K.R.

Kyanite in the "hornfels zone" of the Carn Chuinneag granite (Ross-shire). C. E. TILLEY. *Mineral. Mag.*, **24**, 92–97 (1935).—The formation of kyanite in this region depends upon the prior presence of andalusite and cordierite. Kyanite is formed in areas subjected to regional metamorphism and its formation appears to demand appropriate conditions of temperature and shearing stress. H.I.

Mineral transformations and their equations. A. BRAMMALL. *Sci. Progress*, **30** [120] 616–27 (1936).—Mineral changes by degradation, such as orthoclase → sericite or kaolin, are more frequently studied but are not more important than the reverse kind of change, aggradation, such as the progressive metamorphism of a clay-slate to schist-facies chlorite, kyanite, etc. The problems of modern petrology are in the borderline changes between igneous and metamorphic rocks. Bowen's reaction principle is examined in the light of X-ray work, and equations of change, many familiar but inadmissible, are given and compared with the more standard equations of chemistry. H.H.S.

Production of boric acid in the U.S.S.R. L. E. BERLIN. *Zhur. Khim. Prom.*, **12**, 821–28 (1935).—Datolite is to be used as a raw material at present, the existing deposits of tourmaline and boracites having not yet been sufficiently studied from the technological point of view. The results of laboratory and semi-plant investigations of the method of obtaining B_2O_3 from datolite by extracting with sulfuric acid are given. The method proved to be the more appropriate as compared with other methods. Flow sheets have been worked out and technological data obtained. P.B. & E.S.

Pumpellyite, an abundant hydrothermal and secondary mineral in basic rocks. HANS WILHELM QUITZOW. *Zentr. Mineral. Geol. A*, No. 2, pp. 39–46 (1936).—Pumpellyite, a hydrous calcium aluminum silicate related to clinozoisite is found as (1) a hydrothermal mineral filling cracks and holes in basic lavas, (2) a secondary mineral in albitized diabases and saussurite rocks originating from the anorthite component of basic feldspar and associated with chlorite, epidote, prehnite, etc., and (3) in glaucophane rocks with lawsonite originating from basic plagioclase. Pumpellyite is rare as (1) but widespread (although only in low concentrations) as (2) and (3). In origin it is closely related to lawsonite and epidote, being somewhat later than lawsonite and earlier than epidote. H.I.

Radioactivity as a method for research and definition of geological age of crystalline rocks. M. I. BEZBOROD'KO. *Geologichnuĭ Zhur.*, **1** [1] 125–28 (1935). M.V.C.

Relations of granito-gneiss, schists, and quartzites in West Africa. P. LEGOUX. *Compt. Rend.*, **202** [25] 2090–92 (1936).—The transformations occurring in these strata and the theories involved are discussed. M.H.

Theory of X-ray reflection by crystals. CHAS. MAUGUIN. *Compt. Rend.*, **202** [16] 1375–77 (1936).—Formulas for the reflection of X-rays by a system of planes in a crystal are developed; examples illustrate the application for practical purposes. M.H.

Utilization of leucite. G. GALLO. *Chim. & Ind.*, **34** [4] 763–65 (1935).—G. offers a new process for the utilization of leucite. After treating the mineral with sulfuric acid, the potassium alum precipitated from the solution is crystallized at low temperature. The solution of alum is treated with enough hydrate of potassium to dissolve the potassium aluminate. The pure solution of potassium aluminate is decomposed by a current of carbonic anhydride into aluminum hydrate and potassium carbonate. The potassium hydrate is regenerated by dissolving the potassium sulfate by strontium hydrate; the strontium sulfate is then transformed into strontium carbonate by treating with ammonia and carbonic anhydride; finally, by calcining the strontium carbonate, the oxide and hydroxide of strontium are obtained. M.V.C.

BULLETINS

Report of the Committee on Sedimentation, 1932-34. A. C. TROWBRIDGE, Chairman. *Bull. Nat. Research Council*, No. 98, 246 pp. (1935). Price $1.00. This consists of an introduction by T. and the following papers: (1) "Recent European studies on sedimentation," by Ernest Antevs; (2) "Varved sediments," by Ernest Antevs; (3) "German contributions to the work on sediments, 1930–33," by Hans Becker; (4) "Sedimentation studies at Stanford University, 1932–34," by Elliot Blackwelder; (5) "Studies in glacial sediments, 1932–33," by M. M. Leighton and Enid Townley; (6) "Research on sediments by British Scientists during 1932–34," by Henry B. Milner; (7) "Mineralogy of the sedimentary rocks," by F. J. Pettijohn; (8) "Hydrologic and hydrographic investigations that bear on sedimentation, 1932–33," by Arthur M. Piper; (9) "Chemical papers bearing on sedimentation," by George Steiger; (10) "Current bibliography of recent sediments and source beds of petroleum," by Parker D. Trask; (11) "Notes on various types of sediments," by W. H. Twenhofel; (12) "Studies of marine bottom deposits at the Scripps Institution of Oceanography," by T. Wayland Vaughan; (13) "Some preliminary observations on the oxidation reduction conditions in marine bot-

tom deposits in the Gulf of Catalina," by C. E. ZoBell; and (14) "Terminology of coarse sediments," by Chester K. Wentworth (with notes by P. G. H. Boswell).

J.L.G.

Surface clays and shales of Ohio. C. R. AUSTIN. *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 81, 53 pp. (1934).—A. reports the physical tests and firing behavior of 49 Ohio surface clays and shales. R. F. REA

Chemistry and Physics

Absorption spectra of metallic complexes of dithizon and their analytical significance. HELLMUT FISCHER AND WOLDEMAR WEYL. *Veröffentlich. Kaiser Wilhelm-Inst. Silikatforsch. Berlin-Dahlem.*, **7**, 120–32 (1935).—The results of studies of spectral absorption of colored solutions of dithizon and its metal complexes with Cu(2), Cu(1), Ag, Zn, Cd, Hg(2), Ti(1), Sn(2), Pb(2), Bi(3), Co(2), and Ni(2) with CCl_4 in the field of 400 to 700 $\mu\mu$ are discussed. The possibility of using analytically the absorption curves found for colorimetric measurements is discussed. It was determined that the red colorings obtained from Mn(2) or Fe(2) salt solutions are not due to dithizon complexes but to impurities of Zn. M.V.C.

Adsorption of alkaline cations and alkaline earth in colloidal clay medium. A. DELFORGE. *Chim. & Ind.*, **35** [6] 1276–79 (1936).—In regard to the sol, the adsorption of cations occurs normally according to laws similar to those of permutites, as the normal state of saturation of a sol is 50 and rarely attains values of 70 to 80. Curves show that the adsorption of alkaline bases is not possible if the colloid is already "supersaturated" in alkaline-earth bases. It is understood then that alkaline sols containing excess lime are quickly exhausted of potash, and on the contrary, if the state of saturation is weak, the p_H is low and the earth releases the potash only with difficulty. Liming remedies the situation. M.V.C.

Analysis of feldspar. E. W. KOENIG. *Jour. Amer. Ceram. Soc.*, **19** [9] 257–58 (1936).

Analytical chemistry of beryllium (glucinum). W. R. SCHOELLER AND H. W. WEBB. *Analyst*, **61** [721] 235–41 (1936).—Investigations into the analytical chemistry of Ta, Nb(Cb), and their mineral associates were made. BeO is quantitatively precipitated by tannin from ammoniacal tartrate solution. Its separation from other earth acids is described. H.H.S.

Calculation of the specific heats of mineral oxides (vitreous silicon, lime, alumina) as a function of temperature. A. THURET. *Compt. Rend.*, **202** [16] 1368–69 (1936).—Formulas for the values of true and average specific heats for these three substances were established between −273° and 2600°C; curves are given. M.H.

Collation of experimental data: XXXII. A. ALISON. *Glass*, **13** [5] 200 (1936).—A. discusses control charts for production control. **XXXIII.** *Ibid.*, [6] 236; for Parts **XXVI–XXXI** see *Ceram. Abs.*, **15** [7] 218 (1936). M.C.S.

Color reactions of trivalent and tetravalent titanium. MAX SCHENK. *Helv. Chim. Acta*, **19** [4] 625–39 (1936).—With the tetravalent titanium solutions there is formed, on addition of hydrogen peroxide, an intensively yellow-colored compound. This reaction has been found applicable (in dilute acid and in the absence of fluoride ion) to the colorimetric determination of titanium. The stoichiometric proportion of Ti^{IV} to H_2O_2 is 1:1. A number of other color reactions were found. R.F.R.

Constitution of β iron oxide monohydrate. I. M. KOLTHOFF AND B. MOSKOVITZ. *Jour. Amer. Chem. Soc.*, **58** [5] 777–79 (1936).—Upon prolonged shaking of so-called β ferric oxide monohydrate with dilute hydrochloric acid in a sodium chloride solution, a continuous decrease of the acid concentration is found. The results indicate that the β oxide is not an oxide monohydrate but has the structure βFeO(OH) which is isomorphous with FeOCl and that these two form mixed crystals. F.G.H.

Copper and oxygen. L. L. WYMAN. *Gen. Elec. Rev.*, **37** [3] 120–29 (1934).—The association of these elements in commercial copper is described and shown in a constitution diagram of the copper-oxygen system. W. outlines refining processes, impurities found in copper, variations due to oxygen, embrittlement, microstructure, treatments, and typical failures in copper structures. Illustrated. L.E.T.

Dehydration of kaolins and Tchasov-Yar clay. P. P. BUDNIKOFF AND D. P. BOBROVNIK. *Ukrain. Khem. Zhur.*, **11** [1] 41–55 (1936).—Prosyanaya and Turbovo kaolins and Tchasov-Yar clay are anchimonomineral formations. The kaolins do not give up chemically bound water until about 500°C; Tchasov-Yar clay begins to give it up in the interval 400 to 500°. The dehydration process at 500° approximates $d\ C_o/dt = CK$, where C_o = weight of the sample, C = residue after the reaction in the given interval of time, t, and K = the constant of dehydration. The constants of different kaolins are not equal on account of their different mechanical constitution and the presence of admixtures. Constants for temperatures over 500° were not found, because the chemically bound water evolves in the first 10 min. It can be said that both water molecules bound in kaolin are similar as to their chemical bond and that the dehydration process proceeds as a monomolecular reaction. P.B. & E.S.

Determination of alumina with the aid of 8-ortho-oxyquinoline. M. I. VOLUINETZ. *Ukrain. Khem. Zhur.*, **11** [1] 18–22 (1936).—The method is based on the existence of a silicomolybdene-oxyquinoline complex. The silica is dissolved in the usual way to a concentration of not over 0.25 g. SiO_2 in 100 ml. of diluted HCl acid and treated with a solution of ammonium molybdate (4 g. for 0.025 g. of SiO_2). The solution of silicomolybdate-oxyquinolate obtained precipitates itself; in order to eliminate the simultaneous precipitation of molybdene-oxyquinolate, the concentration of HCl is increased to 3 g. HCl in 100 ml. Further determination can be fulfilled by the volumetric or by the gravimetric method. P.B. & E.S.

Determination of arsenic in reagents by analysis. CASIMIRO BUSQUETS. *Anales Soc. Espaü. Fis. Quím.*, **34** [333] 557–79 (1936).—A short account is given of the methods that have been proposed for the detection of minute quantities of arsenic by its evolution as arsine. As low as 0.0001 mg. of As can be easily detected with the apparatus and procedure described. A colored plate is given which reproduces a series of standard stains obtained

with known quantities of arsenic ranging from 0.0002 to 0.005 mg.; the sensitized paper is dipped into a 10% potassium iodide solution, washed, and dried over sulfuric acid. R.F.R.

Diphenylcarbazide as internal indicator for titration of iron with dichromate. H. E. Crossley. *Analyst*, **61**, 164–69 (March, 1936).—The technique for estimation of Fe is described. H.H.S.

Effects of fluorides on thermal synthesis of calcium silicates: I. S. Nagai and M. Takahara. *Jour. Soc. Chem. Ind. Japan*, **39** [4] 130–32B (1936).—Data showing the relative effectiveness of simple and complex fluorides and glass and feldspar powder on the thermal synthesis of calcium silicates are given. See also *Ceram. Abs.*, **15** [3] 82 (1936). M.V.C.

Equilibria between iron and nickel and their silica-saturated silicates. P. Bardenheuer and E. Brauns. *Mitt. Kaiser-Wilhelm Inst. Eisenforschung*, **17** [9] 127–32 (1935).—Equilibrium between an iron-nickel melt and an iron silicate-nickel silicate slag was determined at 1600°C. Although the reaction is not a double decomposition, the distribution of iron and nickel between melt and slag follows the ideal mass action law. For iron-rich melts, the oxide content is determined by the FeO concentration in the slag, whereas in nickel-rich melts the concentration of NiO is the controlling factor. The solubility of FeO in iron-rich melts is but little influenced by the concentration of Ni up to 50%. The distribution coefficient (O)/(NiO) does not change much with iron content up to 5% Fe. The solubility of NiO in nickel-rich melts decreases with decreasing temperature. J.B.A.

Fractional qualitative and quantitative determination of fluorine. V. Tananaev and G. S. Savchenko. *Khim. Zhur.*, **7**, 229–32 (1935); abstracted in *Chem. Zentr.*, **ii**, 1754 (1935).—The method consists in treating the solution containing fluorine with surplus $AgNO_3$ and precipitating CaF_2 from the filtrate (qualitative determination) or in titrating with an $AlCl_3$ solution (quantitative determination). M.V.C.

Gravimetric determination of barium as anhydrous barium oxalate. C. Díaz Villamil. *Anales Soc. Españ. Fis. Quím.*, **34** [333] 580–86 (1936).—Barium can be determined by precipitating in a neutral solution with 0.098 *M*. ammonium oxalate, filtering, drying at 250° for one hour, and weighing as anhydrous barium oxalate. The results are comparable with the chromate method of analysis and much better than those obtained in the volumetric analysis with permanganate. This method is less accurate than the sulfate method but is more rapid. R.F.R.

Gravimetric determination of selenate. R. Ripan-Tilici. *Z. anal. Chem.*, **102** [9–10] 343–44 (1935).—Lead selenate, being more insoluble and crystalline, is better for gravimetric purposes than barium selenate. The boiling selenate solution (about 0.01 M.) is treated with 0.5 M. lead nitrate solution, drop by drop, an excess of 0.1 to 0.2 cc. being added. After boiling for a few seconds, enough alcohol to provide 30 to 35% in the liquid is added to the solution. The covered beaker is kept at room temperature for 4 to 5 hr. and stirred occasionally. The precipitate is collected in a porous porcelain crucible and washed with 30% alcohol, by decantation at first. It is finally washed with strong alcohol, then ether, kept *in vacuo* for a short while, and weighed. As lead selenate has a strong absorptive power, a large excess of precipitant must be avoided. E.J.V.

Heat capacities of quartz, cristobalite, and tridymite at low temperatures. C. Travis Anderson. *Jour. Amer. Chem. Soc.*, **58** [4] 568–70 (1936).—The heat capacities of quartz, cristobalite, and tridymite from about 50 to 300°K were determined and their corresponding entropies were calculated as 10.06, 10.34, and 10.50, respectively. Illustrated. F.G.H.

Identification of crystalline materials. Classification and use of X-ray patterns. J. D. Hanawalt and H. W. Rinn. *Ind. Eng. Chem., Anal. Ed.*, **8** [4] 244–47 (1936).—The authors show that with the aid of a classification, which is described in detail, it is entirely practical to make effective use of a large library of standard X-ray diffraction patterns for the identification of unknowns, even when the unknown is a mixture of materials. This makes possible a more complete utilization of the unique features of the X-ray diffraction method of analysis. The features which have been found of practical importance are as follows: (1) The substances present show in their true state of chemical combination, especially useful for the study of reaction mixtures. (2) The analysis is very certain, even though only minute amounts of material are available. (3) Substances are studied directly in their "as received" state and are not destroyed. (4) Different crystalline phases, states of hydration, and physical state are observable. (5) The process of preparing the specimen and obtaining the X-ray pattern is very simple. The fundamental limitations of the method lie in its lack of sensitivity to small percentages of the minor constituents and in the noncrystalline nature of many substances. Illustrated. F.G.H.

Metaphosphates of calcium. A. Bouille. *Compt. Rend.*, **202** [17] 1433–35 (1936).—Two new crystalline varieties of calcium metaphosphate were established: *A*, which forms below 400°C, and *B*, which crystallizes at or higher than 565°C. M.H.

Microchemical determination of magnesium with the aid of ortho-oxyquinoline. M. V. Gaptchenko and O. G. Sheintzis. *Zhur. Prik. Khim.*, **9** [3] 541–43 (1936).—A drop of the solution under investigation is treated by ammonia, and a drop of the reagent (5% alcohol solution of *o*-oxyquinoline) is added; a greenish yellow flake-like precipitate appears, from which crystals in the shape of lenses and spheroids form. The observation can be made with a 200 to 300 diameters magnification. The composition of the precipitate is $Mg(C_9H_6NO)_2 2H_2O$. The following method was used for determination of magnesium in limestone and clays. A drop of the solution under investigation and a drop of 10% sodium citrate solution in 2 *N* alkali hydroxide are treated with ammonia, and a drop of the reagent is added. A greenish yellow, fine, amorphous substance is precipitated from which round grains and oblong laminas and then characteristic concretions of magnesium *o*-oxyquinoline form. P.B. & E.S.

Microchemical determination of silica in presence of admixtures. A. D. Vorob'iova. *Zavodskaya Lab.*, **5** [2] 166–67 (1936).—The method (see following abstract) was verified in respect to the influence of different admixtures

on the accuracy of the determination. Ions of $Mn^{\cdot\cdot}$ (in chloride form), $Cr^{\cdot\cdot\cdot}$ (in sulfate form), Mo^{IV} (Na_2MoO_4), and W^{VI} (Na_2WO_4) had practically no influence. With some difficulty, accurate results were attained in the presence of V^{V} ($NaVO_3$). In the case of $Al^{\cdot\cdot\cdot}$, $Fe^{\cdot\cdot\cdot}$, and $Fe^{\cdot\cdot}$ the error attains 3%, 1%, and 1.04%, respectively, making an accurate determination impossible. P.B. & E.S.

Microvolumetric determination of silica in soluble silicates. A. D. Voron'lova. *Zavodskaya Lab.*, **5** [2] 165 (1936).—A few milliliters of the solution investigated, containing from 0.15 to 7.0 mg. of silica in the form of a soluble silicate, are titrated by 0.01 *N* hydrochloric acid with methyl red, and 2 to 8 ml. (depending on the amount of silica) of a reagent consisting of a mixture of NaF and KCl (1:10) are added; 1 to 55 ml. of 0.01 *N* hydrochloric acid are added. After mixing and standing 20 min., 5 to 10 ml. of alcohol are added. After standing 10 min. the excess of HCl acid is titrated by 0.01 *N* NaOH with methyl red. P.B. & E.S.

Preparation and composition of wüstite phases. E. E. Wood and J. B. Ferguson. *Jour. Wash. Acad. Sci.*, **26**, 289–93 (1936).—Attempts to prepare pure FeO by dehydration of ferrous hydroxide and by decomposition of ferrous oxalate were unsuccessful. The recombination of iron and magnetite formed by decomposition of wüstite takes place readily. Reaction between iron and magnetite from extraneous sources is not complete in samples high in iron. Samples of wüstite prepared at 1097°C and 926°C gave 77.05 and 76.9% total iron, respectively. At 727°C the wüstite field extends to at least 76.0% and probably as far as 76.2% total iron. J.B.A.

Products of hydrothermal reaction on clayey substances: II. S. Nagai and T. Suzuki. *Jour. Soc. Chem. Ind. Japan*, **38** [12] 732–37B (1935).—Fire clays, pottery clays, acid earth, and bentonite were heated with sodium hydroxide solution under pressure and without pressure. The reactions which took place are tabulated. **III.** *Ibid.*, **39** [1] 7–8B (1936).—The effect of alkali solutions on high aluminous substances heated with or without pressure was studied. Tables show the decomposition and the percentage of alumina extracted from aluminous raw materials. **IV.** *Ibid.*, [2] 45–46B. **V.** *Ibid.*, [3] 96–98B.—The results of further analyses of the hydrothermal reactions of alkaline solutions on clayey substances of high silica or alumina content are given. For Part I see *Ceram. Abs.*, **15** [1] 44 (1936). M.V.C.

Quick method of determination of SiO_2 in insoluble slags. A. F. Alexandrov. *Zavodskaya Lab.*, **5** [2] 232–33 (1936).—A small sample of acid slag is liberated from its SiO_2 by treating the slag with a mixture of very small quantities of H_2SO_4, HNO_3, and HF; the residue is quickly evaporated, fired at about 1000°, and weighed. FeO and MnO pass to Fe_2O_3 and Mn_3O_4, and a corresponding correction must be allowed for them; other components being present in a very small amount, they do not influence the results appreciably. The SiO_2 content is calculated by difference. The limit of accuracy of the method is about 1%. P.B. & E.S.

Random fracture of a brittle solid. C. C. Lienau. *Jour. Franklin Inst.*, **221** [April] 485; [May] 673; [June] 769 (1936).—L. applied a tentative definition of a statistically homogeneous brittle solid in (*a*) the determination of the average regional and boundary conditions which accompany the production of a random system of new fracture surface, and (*b*) the calculation of the size, mass, and shape probabilities of the resulting system of fragments. P.T.C.

Rapid analysis of clays. S. S. Zhukovskaya. *Zavodskaya Lab.*, **3** [2] 102–109 (1934).—The oxine (oxyquinoline) method allows the components entering into the composition of silicates to be determined directly; it reduces the time needed for an analysis to 2 days, provided SiO_2 be determined from a separate sample. All components can be determined in the presence of silica. The order of determination of separate elements can be changed. The use of electrical furnaces and of platinum is limited to a minimum. A detailed description of the procedure is given. P.B. & E.S.

Sixth Report of the Commission on Atomic Weights of the International Chemical Union. G. P. Baxter, O. Hönigschmid, and P. Lebbau. *Anales Soc. Espaü. Fis. Quím.*, **34** [332] 525–38 (1936). R.F.R.

Surface chemistry. J. Langmuir. *Gen. Elec. Rev.*, **38** [9] 402–14 (1935).—Early and modern theories of adsorption, forces between atoms, and monomolecular films of measurement of caesium-atom films are discussed. L.E.T.

System albite–fayalite. N. L. Bowen and J. F. Schairer. *Proc. Nat. Acad. Sci.*, **22** [6] 345–50 (1936).—The results of a study of phase equilibria at high temperatures in mixtures of albite ($NaAlSi_3O_8$) and fayalite (Fe_2SiO_4) are given. The phase diagram is of the simple eutectic type with the eutectic occurring at 84% albite-16% fayalite with a melting temperature of 1050° ± 5°C. The geological significance of the results is discussed. 2 diagrams. J.L.G.

Tin: detection and colorimetric determination by 1:2 dimercaptobenzenes. R. E. D. Clark. *Analyst*, **61** [721] 242–45 (1936).—Specific reagents for Sn are described. H.H.S.

Volumetric determination of aluminium in kaolin. V. P. Zemlyanitzuin. *Zavodskaya Lab.*, **3** [2] 115 (1934).—One-half gram of kaolin (dried at 120° and finely screened) is mixed with 5 to 6 g. of fine sodium or potassium hydroxide and carefully fused in a crucible or in a test tube. When the mixture begins to boil, it is cooled and afterward lixiviated until completely dissolved. HCl is added until the acid reaction appears distinctly; after the mixture is diluted to 500 cc., the acidity is neutralized with Tropeolin OO or another very accurate indicator. After neutralization, a titration is made with a $CO(OH)_2$ or a 0.1 *N* NaOH solution with phenolphthalein as indicator. The amount of cubic centimeters is multiplied by 40 and by the lime solution factor for aluminium. As the iron also precipitates, it must be determined separately and subtracted. P.B. & E.S.

Volumetric determination of fluorine after precipitation as potassium fluosilicate. A. A. Wassilieff and N. N. Martianoff. *Z. anal. Chem.*, **103**, 107–13 (1935).—*Soluble fluorides.* The sample (equal to 0.2 g. NaF) is dissolved in 15 cc. of water, and the solution is treated with 15 cc. water-glass solution (0.01 g. SiO_2/cc.), 2 or 3 drops of methyl-orange indicator, 1 g. KCl, and then with 1:1 HCl added drop by drop until acid with an excess of 2 or 3 drops. After sufficient alcohol to make a 50% solution has been

added, the liquid is allowed to stand at least one hour. After filtering, the beaker is washed twice with 50% alcohol containing 2 g. KCl/100 cc., and the precipitate and filter are washed three times, care being taken to wash the edge of the paper. The volumes of the mother liquor and washings are marked on the beaker in which they are collected. The washed filter is spread out in the beaker used for precipitation, covered with 100 cc. CO_2-free warm water, and titrated with 0.1 *N* NaOH with phenolphthalein as the indicator. Toward the end of the titration, the solution is heated nearly to boiling; 1 cc. is equivalent to 0.0063 g. NaF. The authors determined solubility corrections of 0.0023 g. K_2SiF_6/100 cc. of mother liquor and 0.0010 g./100 cc. for the washings. *Insoluble fluorides.* A sample of fine powder of about 0.5 g. is fused with 1.25 g. of finely powdered quartz and 6 g. of Na_2CO_3 in a platinum crucible until no more gas is evolved. After the cake is dissolved and the crucible rinsed carefully, the solution is heated until the mass has disintegrated completely. The liquid is then transferred to a 300-cc. graduated flask, treated in a bulk of 200 cc. with 20 g. powdered ammonium carbonate, and allowed to stand for one hour at 40°C. After cooling to room temperature and adjusting the volume, the liquid is mixed and allowed to stand overnight. After filtering, 200 cc. of filtrate are evaporated to 30 cc. on a steam bath, and the solution is treated as described for soluble fluorides (1 cc. 0.1 *N* NaOH is equal to 0.00285 g. F). E.J.V.

Volumetric determination of silica in silica brick, quartzites, clays, and grog with the use of oxyquinoline. M. I. Voluinetz. *Zavodskaya Lab.*, **5** [2] 162–64 (1936).—The sample (0.25 g.) is fused with 5 g. NaOH in a nickel crucible and lixiviated with water; after dilution in water to 200 ml. it is heated nearly to the boiling point with an addition of 30 ml. HCl (1.19) to dissolve the basic salts that have formed, and, after cooling, the solution is poured in a flask; 100 ml. of solution *a*, 20 ml. of molybdate of ammonia solution (200 g./liter), and 5 ml. of HCl (1:1) are added, and after closing the flask with a rubber stopper it is heated on a water bath for 10 min. at about 80°; 20 ml. of HCl are added, and the silicomolybdene-oxyquinoline complex is precipitated by pouring in 1.4% of a hydrochloric acid solution of oxyquinoline; 0.1 ml. of this solution corresponds to about 0.6% of SiO_2. After precipitation, the flask is closed once more and heated 10 min. at about 60 to 70° to increase the size of the crystals of the complex; after cooling, the whole is filtrated. To 25 ml. of the sample, 30 ml. of HCl (1:1), 30 ml. of an oxalic acid solution (80 g./liter), and 130 ml. of water are added, then 12.5 ml. of a 0.1 *N* bromate-bromide solution, 5 ml. of a 10% KI solution, and 5 ml. of a 0.5% starch solution are added and the excess of iodine is titrated preliminarily by a 0.05 *N* hyposulfite solution. To 100 ml. of the filtrate are added 12.5 ml. of the oxalic acid solution, 100 ml. of HCl, 225 ml. of water, and a certain quantity of bromate solution, depending on the quantity of hyposulfite used in the preliminary titration. After standing 2 min., 5 ml. of a 10% solution of KI and 5 ml. of a starch solution are added, and the iodine evolved by the excess of bromine is titrated by hyposulfite. The deviations of data obtained by this method from the weight method do not exceed 0.30%, and the time needed for one determination takes only 3 hr. P.B. & E.S.

Volumetric method of determination of small amounts of boron in natural solutions. N. V. Tageeva. *Zhur. Prik. Khim.*, **8**, 528–35 (1935).—The methods of titration of boric acid by 0.1 *N* alkali with phenolphthalein as indicator and of titration of boric acid with 0.02 *N* alkali in presence of phenol red were checked and partly verified. It has been found that the first method gives adequate results without preliminary distillation in determining absolute amounts of B_2O_3 over 2 mg. in natural solutions (limit of error 0 to 3%). The second method gives adequate results for amounts of B_2O_3 not under 0.5 mg. (limit of error 1 to 3%). Small amounts of boron in solutions containing colloidal alumina hydrate can be determined volumetrically with a sufficient accuracy after the separation of the solution from the precipitate by filtration. The volumetric determination of small amounts of boron after separation by distillation gives accurate results (error 0.1 to 6%) if the distillation is made with a small amount of sulfuric acid; the distillation is to be conducted in the case of the presence of substances impeding the direct determination of boron. Determinations in natural solutions (oil-containing and thermal waters) by both methods gave satisfactory results. P.B. & E.S.

Zincate method of sulfur determination in slags. N. A. Tananaev and I. I. Antoshchenko. *Ukrain. Khem. Zhur.*, **10** [1] 27–29 (1935).—Sodium zincate is used for the determination that takes place according to the following reactions: $2NaOH + H_2S = Na_2S + 2H_2O$; $Na_2S + Zn(NaO)_2 + 2H_2O = ZnS + 4NaOH$; $ZnS + I_2 = ZnI_2 + S$. By titrating the excess of iodine, the amount of zinc sulfide, *i.e.*, of sulfide sulfur, is obtained. Before titrating, the alkaline solution is neutralized by hydrochloric acid. A simple arrangement of apparatus is described. The determination takes about 30 min. P.B. & E.S.

BOOKS

Chemical Analysis (Die chemische Analyse. Ausgewaehlte Untersuchungsverfahren für das chemische Laboratorium). L. W. Winkler. 167 pp. 24 illustrations. Ferd. Enke, Stuttgart; G. E. Stechert & Co., New York, 1936. 167 pp., 24 illustrations. Price 15.80 Rm. The first part of this book appeared in 1931. The second part brings a variety of new testing methods for analytical work. The book is divided into two parts, *viz.*, physical and chemical tests. The first part has the following titles: determination of density, melting and boiling points of oils and salts, solubility of gases in water, solubility of carbon dioxide and nitric oxide in alcohol, etc. The second (chemical part) deals with such methods as iodometric and bromometric tests, colorimetric tests, etc. L. E. Theiss

Colloid-Chemical Technology (Kolloidchemische Technologie). R. Liesegang. 3d ed. Theodor Steinkopff, Dresden, 1935. 1085 pp., 376 illustrations. Price 68.00 Rm. From this handbook dealing with the colloid-chemical problems in the chemical industry, several chapters have been published as separate issues, such as Keramik (Ceramics), by H. Kohl, 52 pp., 20 figs.; Portland Zement (Cement), by G. Frenkel; Gips (Plaster), by Paul Neuschul-Prag; and Glass, by R. Ed. Liesegang, 40 pp.,

12 figs. Price each edition 7.00 Rm. See *Ceram. Abs.*, **11** [11] 597 (1932). L.E.T.

Analytical Chemistry: Vol. II, Quantitative Analysis. F. P. TREADWELL. Translated, enlarged, and revised by William T. Hall. John Wiley and Sons, Inc., New York, 1935. 8th ed. 858 pp. Price $6.00. Reviewed in *Jour. Amer. Chem. Soc.*, **58** [2] 381 (1936). F.G.H.

Flotation Concentration of Minerals (Schwimmaufbereitung). W. PETERSON. Theodor Steinkopff, Dresden, 1936. 337 pp. Price unbound 18 Rm; bound, 19.50 Rm. Reviewed in *Jour. Amer. Chem. Soc.*, **58** [6] 1065 (1936).—This monograph presents a well-documented account of the application of physicochemical principles to the separation of valuable minerals from their accompanying gangue minerals. It reviews the significant literature up to 1933. More than half of the text material is concerned with the theoretical aspects of surface chemistry as applied to modern flotation practice. The current methods of flotation of the various minerals are given in tabular form after the general discussion of the reagents used in the flotation of the several groups of minerals. F.G.H.

Landolt-Börnstein Physical-Chemical Tables (Landolt-Börnstein Physikalisch-chemische Tabellen). **Vol. III, Part II.** W. A. ROTH AND K. SCHEEL. Julius Springer, Berlin, 1936. 5th revised ed. 1080 pp. Price 162 Rm. Reviewed in *Jour. Amer. Chem. Soc.*, **58** [2] 382 (1936). F.G.H.

Physical Chemistry for Colleges. E. B. MILLARD. McGraw-Hill Book Co., Inc., New York, 1936. 4th ed. 524 pp. Price $3.75. Reviewed in *Jour. Amer. Chem. Soc.*, **58** [5] 864 (1936). F.G.H.

Textbook of Quantitative Analysis. WILLIAM THOMAS HALL. John Wiley and Sons, Inc., New York, 1935. 350 pp. Price $3.00. Reviewed in *Jour. Amer. Chem. Soc.*, **58** [3] 539 (1936). F.G.H.

Textbook of Quantitative Inorganic Analysis. I. M. KOLTHOFF AND E. B. SANDELL. Macmillan Co., New York, 1936. 749 pp. Reviewed in *Jour. Amer. Chem. Soc.*, **58** [6] 1066 (1936). F.G.H.

Thermochemistry of the Chemical Substances. F. RUSSELL BICHOWSKY AND FREDERICK D. ROSSINI. Reinhold Publishing Corp., New York, 1936. 464 pp. Price $7.00. Thermochemical values for all inorganic substances and all organic compounds of one and two carbon atoms for which data have ever been obtained are given, making it possible to compute the heats of chemical reactions. A complete record of the state of the data for any given substance or reaction is given in the citations and references. There are four main sections to the book: (1) Introduction; (2) Tables of Heats of Formation; (3) Text; (4) References. The tables contain 5840 values of heats of formation, and, in addition, 350 values of heats of transition, fusion, vaporization, or reaction for substances for which the heat of formation is not known. Adequate description is given of the physical state of each substance. The chemical substances are listed in the tables in a logical and simple manner, making easy the finding of any compound.

PATENTS

Production of alkali-metal silicates. CANDIDO CAVEZZALE AND GIUSEPPE CURRELI. U. S. 2,047,614, July 14, 1936 (June 14, 1933). The process of producing an alkali-metal silicate comprises reacting pumice with a solution of an alkali-metal hydroxide, the constituents of the reaction mixture being regulated so as to produce when the reaction is complete a solution of not more than substantially 26° Bé density, filtering the reaction mixture when the reaction between the alkali-metal hydroxide and the pumice is substantially complete, and concentrating the filtrate so obtained.

Recovery of selenium. F. F. POLAND (American Smelting and Refining Co.). U. S. 2,048,563, July 21, 1936 (March 8, 1934). The process for treating anode mud, slimes, sludges, etc., which contain copper, selenium, and precious metals comprises leaching them to remove copper, and, without intervening high-temperature treatment, subjecting the residue containing substantially the original selenium content and precious metals to oxidation in the presence of molten caustic alkali, and so controlling the oxidation that the selenium is converted *in toto* to alkali selenite without the formation of any substantial amounts of selenates, leaching the resultant fusion product whereby the alkali selenite enters into solution and the precious metals remain as insoluble residue, and precipitating selenium from the solution thereby recovering substantially the entire selenium content of the original material as one end product.

General

Aspects of the chemistry of silicosis. C. M. JEPHCOTT. *Can. Pub. Health Jour.*, **26**, 608–10 (Dec., 1935); abstracted in *Ind. Hyg. Abs.*, **18** [3] 39 (1936). H.H.S.

Clay products in East Midland potteries. ANON. *Trade & Eng.*, **38** [864] viii (1936).—A list of the chief manufacturers of brick, tile, sanitary ware, electrical fittings, domestic pottery, and "Derby chinaware" in the East Midland district of England is given. A.B.S.

III, Effects of various treatments upon the aging of a ceramic body. D. P. GLICK. *Jour. Amer. Ceram. Soc.*, **19** [9] 240–42 (1936); for Part II see *ibid.*, [7] 209–12.

German Engineering Association (Vereins Deutscher Ingenieure): **80th Celebration.** *Zentr. Gewerbehyg. Unfallverhüt.*, **23** [3–4] 66–67 (1936).—The German Engineers held a jubilee, May 26 to 29, 1936, for their 80th year of organization, together with the Darmstadt Technical Hochschule, as it celebrated its 100th year of existence. Several other German Engineering Societies (listed) participated in the ceremonies. Of especial interest at the meetings were the papers on dust technique, the removal of dust from the air of work places, indoors or out, underground, or wherever it can injure workers. K.R.

Glass at the Leipzig fall exposition. ANON. *Glashütte*, **65** [36] 559–60 (1935).—A brief review of the various types of glassware and enamelware exhibited is given. M.V.C.

History of Norton Company. ANON. *Bull. Amer. Ceram. Soc.*, **15** [8] 295–96 (1936).

Holtzmann's 60th birthday and jubilee for 30 years'

service as province industrial physician. *Zentr. Gewerbehyg. Unfallverhüt.*, **23** [3–4] 65–66 (1936).—Friedrich Holtzmann's 60th birthday was celebrated April 26, 1936. May 1, 1936 commemorated his 30th year as Baden's industrial doctor. He is Germany's oldest industrial physician. Porcelain workers and stone industrials everywhere are indebted to his numerous works in their behalf on dust injuries, especially those of silicosis. German workers have him to thank for every kind of industrial protection. His medical education was completed in Strasburg; during his assistantship he became so interested in the social aspects of industry and public health questions that he was appointed Factory Inspector in May, 1906. Theoretically he was well prepared for the work; the new position gave him first-hand contact with industry. His papers on the working conditions for women in the Baden textile industries, good light as imperative for every worker in any industry, industrial noise as affecting the hearing of employees sooner or later, and the injurious effects of pneumatic pressure upon workers represent part of industry's debt to his thorough and heartfelt investigations. He is familiar with every question and aspect of industrial medicine and a frequent contributor to the *Zentr. für Gewerbehygiene*. He still instructs in the Technical College, Karlsruhe, and continues to work on the Medical Committee of the German Society for Industrial Medicine. He is a permanent member of the International Commission. K.R.

Industrial injury to the lungs (pneumoconiosis) in porcelain workers. C. Kaestle. *Fortschr. Gebiete Röntgenstrahlen*, **53**, 267–74 (1936); abstracted in *Ind. Hyg. Abs.*, **18** [6] 85 (1936).—Gossner, of the Mineralogical Institute in Munich, did not find the smallest traces of sericite in the porcelain dust of the Bavarian industry and in the chalk dusts of the Nuremberg industry. In the upper Bavarian coal, *i.e.*, in the rock which accompanies the coal, important quantities of sericite were present. In previous investigations Kaestle and Koelsch ascertained numerous cases of lung fibrosis among the porcelain workers and among the chalk workers of Nuremberg, but not a single one among the coal miners, disproving, at least for these industries, Jones' theories. Of the 179 porcelain workers examined in 1925–27, 10 died of koniosis, *i.e.*, konio-tuberculosis, and only 73 could be examined again; during the interval between the two examinations the hygienic conditions were improved. In 68% of the examined workers, the lung conditions became worse. Predisposition plays an important rôle in the solution of the illness, and the usual classifications do not give valuable indications of the actual degree of invalidity. When the dust contained great quantities of free silica, mottlings were observed. Lung damage among porcelain workers often was coalescence of the nodular fibrosis. Severe cases of silicosis can develop even after the work is discontinued. E.J.V.

It's well to watch the plastics. Rufus H. Jones. *Nation's Business*, **24** [7] 18 (1936).—A general survey of the plastic industry is given. Plastics, their manufacture, market, use, different shapes, colors, etc., and their versatility are discussed. An insight into the architectural materials field is also given. The slow substitution of plastics for other building materials is cited. P.T.C.

Lead content in duodenal juices in cases of saturnism. Preliminary report. N. Aliavdin and E. Peregood. *Jour. Ind. Hyg.*, **18** [3] 139 (1936).—An examination of 28 lead-poisoned people showed a lead content in the duodenal juices in most cases. Not all cases of clearly defined lead poisoning show lead in the duodenal juice; in about one-third of these cases some lead may be found, simultaneously, both in the urine and in the duodenal juice, but its concentration in the duodenal juice exceeds ten times that in the urine; one-third of the cases show a high concentration of lead in the duodenal juice and a complete absence of it in the urine. E.J.V.

Liability for patent infringement. L. T. Parker. *Combustion*, **7** [6] 33–34 (1935).—A review of numerous court decisions showing that it is unlawful to make, sell, or use a patented device without permission or to repair a patented article to the extent of rebuilding or renovating it is given. Joint infringement liability and recent decisions governing control over resale of a patented device are explained. H.E.S.

Market sentries of small business. Mark A. Wodlinger. *Nation's Business*, **24** [4] 20 (1936).—An authority in the field points out some pitfalls that spot the path of the newcomer in research and suggests a method by which the small concern as well as the large one may keep abreast of the scientific developments in its own field. P.T.C.

Materials handling. Anon. *Factory Management & Maintenance*, **94** [6] S262–65 (1936).—All manufacturers are handling materials. A common-sense approach to handling costs is discussed. Plant layout and handling are fitted into the scheme. J.L.G.

Mineralogical composition of air-borne foundry dust. Theodore Hatch and Charles B. Moke. *Jour. Ind. Hyg.*, **18** [2] 91–97 (1936).—Air-borne foundry dust exhibits striking changes in composition with particle size. The percentage of combustible matter and acid-soluble iron, carbonates, etc., increases with decreasing size. The proportion of clay and other silicates varies, without a definite trend, with size. The quartz content, however, becomes less as the size decreases, and for particles under 2 microns (over 90% of the total number of particles) it amounts to only $^1/_6$ or even $^1/_{25}$ of the per cent of silica in the fraction greater than 10 microns. True dust-producing processes in the foundry, such as sand-chipping and sandblasting, show higher amounts of quartz in the less than 2 micron fractions because coarse grains of silica are broken down into microscopic particles by these processes. This explains why sand chippers and blasters develop more silicosis than other foundry workers. The determination of the composition of industrial dust for the purpose of evaluating its silicosis-producing capacity should be made on several size-fractions of the air-borne dust actually inspired by the workers rather than upon rafter samples or other deposits of coarse particles. E.J.V.

Occupational diseases among cement workers in the department of Gironde (France). P. Derville and P. Carrere. *Méd. du Travail*, **7**, 243–47 (Nov., 1935); abstracted in *Ind. Hyg. Abs.*, **18** [3] 40 (1936).—The authors recognize a dermatitis as important among cement handlers but of no seriousness in cement manufacturers. E.J.V.

Plant layout. Allan H. Mogensen. *Factory Manage-*

ment & Maintenance, **94** [5] S246–60 (1936).—The topics considered are product *vs.* process control, the process chart as a layout tool, making the templet layout, and installing the layout. Illustrated. J.L.G.

Rock wool in relation to health. L. T. Fairhall, S. H. Webster, and G. A. Bennett. *Jour. Ind. Hyg.*, **17** [5] 263–75 (1935).—To determine the effect of rock-wool insulation on health, cats were subjected to cold vapor, hot vapor, and dust experiments with varying concentrations of rock wool. The chemical data obtained indicate no hygienic hazard. Histological examination of the lungs, liver, and kidneys reveals no constant or significant pathological changes. In the dusted cats there was evidence of inhalation of considerable quantities of silicate and the accompanying changes in the lungs were those which might be expected from such foreign matter. E.J.V.

Silicosis problem from employer's standpoint. Alfred C. Hirth. *Nat. Glass Budget*, **52** [4] 8 (1936).—Silicosis is an occupational disease which is of equal importance to the employer, the employee, and the general public. It is being combated by the employer through the modification and improvement of the processes wherein individuals may contract such a disease. An adoption of wet mixing of batches in which silica is a component, the wetting and spraying of mines where silica is claimed or where it is handled in the process of claiming other materials, and the careful control of sandblasting equipment to prevent the leakage of the fine dust represent a few of the precautionary methods being adopted to combat silicosis. M.C.S.

Thermal and sound insulation. André Kessler. *Tech. moderne*, **28**, 297–302 (1936); abstracted in *Chem. Zentr.*, **i**, 4963 (1936).—The characteristic properties of various insulating materials, such as cell concrete, pumice stone, slag wool, lead insulation, etc., are discussed in detail. M.V.C.

Urinary excretion of silica in nonsilicotic humans. L. J. Goldwater. *Jour. Ind. Hyg.*, **18** [3] 163–66 (1936).—Studies involving variations in specific gravity and 24-hr. urinary silica excretions in persons receiving known diets were made. Determinations of the urinary silica excretion of nonsilicotic humans apparently indicate that (*a*) urinary silica concentration may show wide variations depending on the specific gravity of the urine, (*b*) the same individual on a constant diet may show wide fluctuations in daily silica output and urinary silica concentration, and (*c*) different individuals on similar diets may show great differences in urinary silica output and concentration. Great caution should be observed in interpreting urinary silica findings. E.J.V.

BOOKS

Chemical Formulary. Vol. III. H. Bennett. D. Van Nostrand Co., New York, 1936. 566 pp. Price $6.00. This volume is a continuation of the two previous volumes, and the formulas included cover a great many new products. The section covering materials of construction, in which are included many ceramic formulas, is particularly interesting as many of the newer developments in the metallurgical and ceramic fields are given. Practically every phase of industrial chemistry is treated. For **Vol. II** see *Ceram. Abs.*, **14** [11] 296 (1935). M. C. Shaw

Dust (Staub). **Vol. I.** Published by Staubbekämpfungsstelle. Wilhelm Knapp, Halle, 1936. 170 pp. Price, unbound, 3.75 Rm; bound, 5.00 Rm. This volume is published by the Union of German Industrial Associations for Fighting Dust and contains several original articles dealing with the fighting of dust in various industries and a series of abstracts from papers published in various periodicals. M. V. Condoide

Techniques of safety measures in the building, ceramic, and refractories materials industries. R. L. Pevzner. Chief Ed. Office, Bldg. Literature, Leningrad, 1936. 174 pp., 97 figs. Price 2R 35k. This book deals with the dangers and injuries encountered in the so-called silicate industries. The necessary measures for preventing these injuries and combating the dangers are discussed. S. I. Perkal

PATENTS

Alkali silicate heat- and sound-insulating composition. N. M. Elias. U. S. 2,047,016, July 7, 1936 (Sept. 26, 1930). A new manufacture comprises relatively insoluble masses consisting solely of substantially anhydrous cellular alkali borate silicate.

Ceramic-like articles and process of manufacturing. N. V. Mij. tot Beheer en Exploitatie van Octrooien. Brit. 448,293, June 17, 1936 (April 11, 1934); addition to 428,329, May 22, 1935.

Lightweight concrete and ceramic aggregate therefor. C. K. Harding. U. S. 2,046,071, June 30, 1936 (Feb. 5, 1930).

Manufacture of cast slag articles. Tracy Bartholomew. U. S. 2,044,198, June 16, 1936 (Sept. 9, 1932).

Treatment of slag. Tracy Bartholomew. U. S. 2,044,199, June 16, 1936 (Sept. 9, 1932).

FALL MEETING ANNOUNCEMENTS

OHIO CERAMIC INDUSTRIES ASSOCIATION

Columbus, Ohio, October 9 and 10

(1) Meetings on Campus, Ohio State University, Friday and Saturday
(2) Saturday, October 10: COMPLIMENTARY LUNCHEON, 12:00 M. (sharp). Engineering Experiment Station Building
(3) Football Game: University of Pittsburgh–Ohio State University (Tickets available at Lord Hall, O. S. U.)

GLASS DIVISION, AMERICAN CERAMIC SOCIETY

Hotel Riverside, Cambridge Springs, Pa., October 23 and 24

Program: Review of Papers Given at the Second International Congress on Glass by F. C. Flint, Donald Sharp, S. M. Scholes, Games Slayter, J. E. Frazier, Louis Navias, E. L. Hettinger, J. C. Hostetter, N. W. Taylor, and A. N. Finn

Saturday Afternoon: Golf Tournament

ART DIVISION, AMERICAN CERAMIC SOCIETY

Lord Baltimore Hotel, Baltimore, Md., October 30 and 31

Program: Papers and Discussions by L. E. Barringer, C. M. Harder, T. A. Klinefelter, Mrs. Mabel C. Brady, H. E. Winter, A. S. Watts, T. E. Ryder, L. F. Beckerman, F. C. Flint, H. R. Bacher, A. V. Bleininger, W. A. Weldon, A. E. Baggs, R. G. Cowan, F. H. Norton, M. E. Holmes, and William Russell

Scheduled Trips: Walters Art Gallery, Baltimore Museum of Art, and The Maryland Institute, Baltimore, Md., and The Freer Art Gallery, Washington, D. C.

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